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A SPECTROMETER FOR ELECTROMAGNETIC RADIATION.[1]

A. D. Cole

At various times for some years the author has carried on experimental studies of electric radiation, measuring the amounts reflected, transmitted, absorbed, refracted and diffracted under different conditions.[2] For these purposes the separate pieces of apparatus were brought into suitable relation to one another by temporary mountings, somewhat deficient in accuracy and in convenience. Such makeshift arrangements have been common with most workers in this field. This is perhaps due to the influence of the classic pioneer work of Hertz[3] in 1888. In his case such arrangements were necessary because the long wave-lengths he used required apparatus of large size, which was, therefore, heavy and inconvenient. So its different parts were mounted and moved as separate units. Righi,[4] however in the early nineties showed how it is possible to obtain strong electrical radiation whose wave-length does not exceed a few centimeters, so that it then became possible to use apparatus of much more convenient dimensions.

There was a three-fold reason for the design of the apparatus about to be described. The first was the need of a more compact and easily adjustable mounting for the various pieces of apparatus used in continuing a research on diffraction phenomena, upon which a preliminary report was presented at the New York meeting of the A.A.A.S. The second reason was the desire to have a compact arrangement by means of which advanced students could repeat the experiments of Hertz, Righi, Boltzmann and others.

[1] Read before A.A.A.S., Section B. and the American Physical Society, December 31, 1908.

[2] A. D. Cole, *Wied. Ann.*, vol. 57, p. 290, '96—*Phys. Rev.*, 4, p. 50 '96– *Elec. World*, September, '96. *Phys. Rev.*, 7, p. 225; *ibid.*, 20, p. 268, '05 *ibid.*, 23, p. 238, '06.

[3] H. Hertz, *Wied Ann.*, 36, p. 769, or *Phil. Mag.*, 5, 27, p. 369.

[4] A. Righi, *Rend. Lincei.* 1893. p. 333.

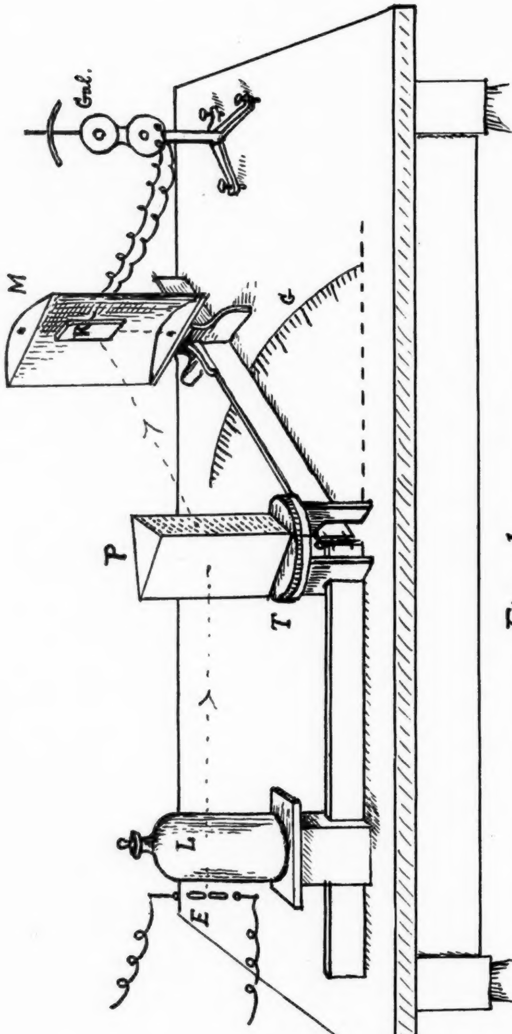


Fig. 1.

The third object was to secure the means of demonstrating the optical analogies of electric waves as completely and rapidly as possible in the lecture room.

It seemed that all three of these objects would be best attained by the use of a mounting for the several parts of the wave apparatus similar to a laboratory spectrometer for light. Such a design has indeed been used by Righi.[5] His apparatus, however, was only roughly quantitative and its indications could be seen by but a single observer at once. Furthermore, it was clumsy and lacked rigidity.

In the present design, an attempt has been made to secure a form sufficiently elastic to adapt it to a wider variety of uses than that of either Hertz, Righi or Lodge,[6] and so develop very completely the analogy bet · een electrical radiation and light.

The apparatus consists of a suitable mounting for an exciter or generator of electrical waves and a similar mounting for the receiver. Each of these is supported by a moveable arm, swinging horizontally about a common vertical axis which is also the axis of a revolving central table. Upon this a prism, grating, diffraction slit or other optical device can be placed. The exciter and receiver are as a rule each mounted in the focal axis of a cylindrical parabolic mirror, as in the original experiments of Hertz. Either or both of these converging mirrors however can be replaced by a cylindrical lens. An ordinary 5-lb. acid bottle filled with kerosene, benzine or gasoline makes a satisfactory concentrating lens. If the exciter is placed about 1.5 cm. behind it, the conditions for a "parallel beam" are secured. The illustration, (fig. 1) shows the exciter mounted at E behind the lens L and the receiver R (enclosed in a small pasteboard box) at the focus of the parabolic mirror M. A prism P is placed upon the revolving table T so as to receive the radiation concentrated by L and refract it to the receiver. The exciter is shown only diagrammatically in the figure. It is a modified Righi exciter consisting of two small cylinders with rounded ends, separated by an oil-filled spark-gap. A continuous flow of kerosene oil passes through this spark-gap. This exciter has been described by the author in *Phys. Rev.*, vol. 23, p. 241, (Sept., '06). [Some features of it have

[5] A. Righi, *Die Optik der Electrischen Schwingungen*, p. 9.

[6] O. Lodge, *The Work of Hertz and Some of His Successors*, p. 33.

been described more fully in an earlier paper in the same journal, *Phys. Rev.*, vol. 7, p. 226 (Nov., '98)]. The receiver used is a Klemencic thermo-junction made of fine iron and constantin wires. An early form is described in *Phys. Rev.*, vol. 4, p. 54 (July '96) and the form lately used in *Phys. Rev.*, vol. 20, p. 268 (April '05). This receiver is used in connection with a low-resistance Kelvin galvanometer of fairly high sensitiveness. The receiver is tuned to the period of the exciter by use of little sliding tubes as described in *Phys. Rev.*, 20, p. 269. Hertz used a receiver whose natural period was longer than that of his exciter and Righi one of shorter period than that of his exciter, but there are some advantages in having both of the same period.

To avoid confusion in the figure, some details of the apparatus are not shown. For instance, each of the parabolic mirrors is actually mounted so that it may be revolved about a horizontal axis *aR*. Thus the focal axis of each can be made horizontal or vertical, or may be set at any desired angle to that of the other, the angular position of each being read on its graduated circle. A third graduated arc *G* shows the angle which the two revolving arms, carrying exciter and receiver, make with each other. A fourth graduated circle *T* shows the angle through which the prism table is turned.

To keep the apparatus of convenient dimensions a wave-length of 10 to 15 cm. is used. This enables good results to be obtained with apparatus of moderate dimensions. For example, the aperture of the parabolic mirrors is about 35 × 33 cm., the two revolving arms are one 100 cm. and the other 120 cm., the prism-table 26 cm. in diameter, prism and lenses 22 cm. high, plane mirrors 30 cm., square, etc. In contrast with these dimensions Hertz's mirrors were of 200 × 120 cm. aperture, his gratings and his smallest plane mirror each 200 × 200 cm.; his prism was 150 cm. high and weighed more than 1300 pounds.

To illustrate the use of the apparatus a brief account follows of the method of performing some of the classic experiments of Hertz and others who have since brought the optical analogies of electrical radiation to convincing completeness. (1) *Proof of the existence of stationary waves by interference of direct radiation with that reflected by a plane surface.* The disposition of apparatus is shown in Fig. 2a. The exciter *E*, mounted in its cylindrical mirror, radiates toward the receiver *R* and the plane mirror *M*

placed immediately behind it. The radiation directly received at *R* interferes with that reflected from *M*. By shifting *M* back about 2 cm. at a time the phase relation of the two waves is changed and a system of nodes and loops obtained. In Hertz's original experiment a mirror 13 feet high was used; with our apparatus we commonly use one about one foot square. Fig. 3 shows the results of such an experiment with a mirror only 4 inches square. Distances

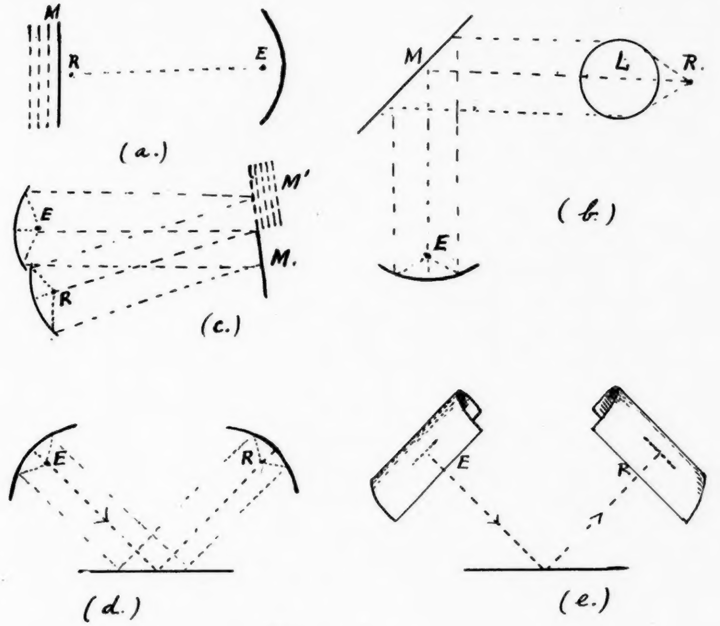


Fig. 2.

of the plane mirror behind the receiver are plotted as abcissae and the corresponding galvanometer deflections as ordinates. Two maxima and minima are well shown. With a mirror 1 foot square 3 maxima and 4 minima appear. (See *Phys. Rev.*, vol. 23, p. 244.)

The use of a thermojunction receiver (whose indications are proportional to the energy received) shows the rate of damping-out of the stationary waves, as well as the position of the nodes.

(2) *Rectilinear Propagation.* (Cf. Hertz, *Ausbreitung der electrischen Kraft*, p. 189). For this experiment the two revolving arms are brought into the same straight line, and exciter and

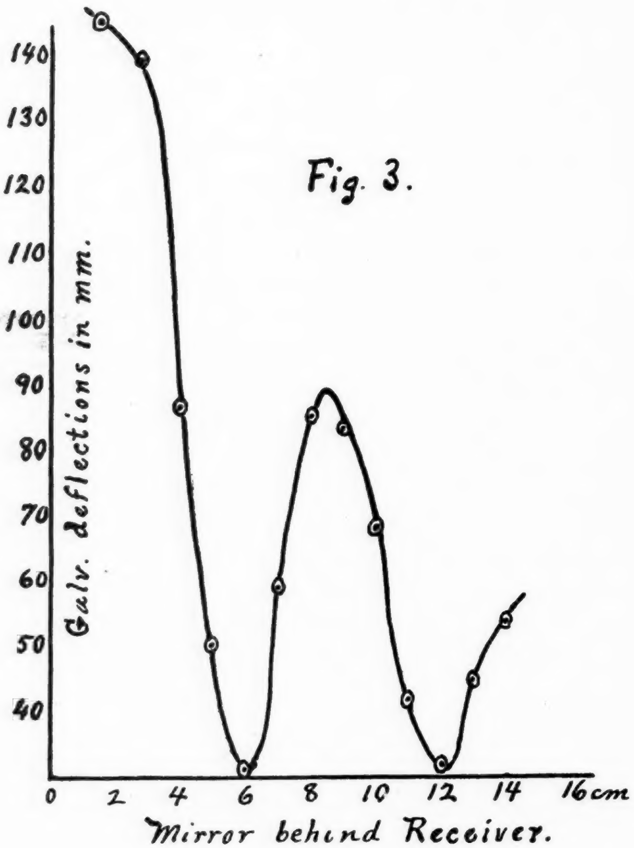


Fig. 3.

receiver placed about 1 meter apart. A metallic screen having about the dimensions of the aperture of the parabolic mirrors—say 35 cm. square—is placed upon the central table midway between them. The effect on the receiver is thus almost entirely

cut off, but only when the screen center is on the straight line connecting exciter and receiver. Ordinary sheet zinc is used for the screen.

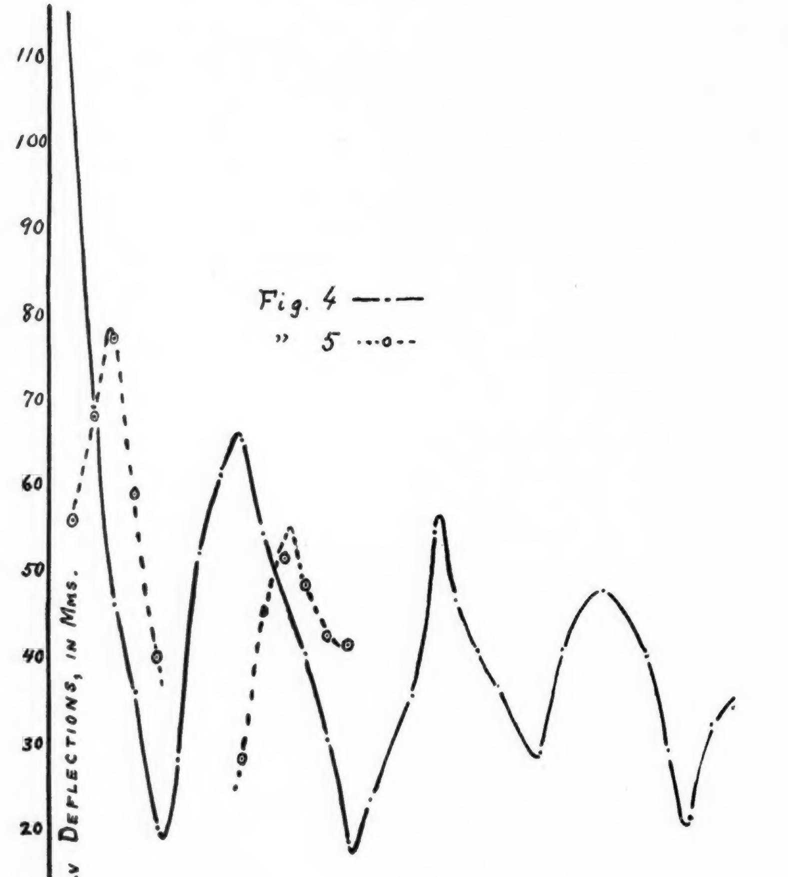
(3) *Polarization.* In place of Hertz's huge polarization grating of parallel wires, we use a piece of cardboard, 35 cm. square, provided with parallel strips of tinfoil, each 2 mm. wide and 1 cm. apart.

(4) *Reflection.* Hertz's experiment showing the equality of the angles of incidence and reflection by a plane mirror, is readily repeated with the 35 cm. square sheet of zinc used in 2. The arrangement of apparatus is shown diagrammatically in fig. 2, *b*.

(5) *Refraction.* This is illustrated already in the action of the "bottle lens." Its efficiency in concentrating the radiation is easily shown by removing it in such an experiment as the last named. The effect on the receiver immediately falls to about one-fifth that before obtained. The experiment which Hertz performed with his gigantic 1300-lb. prism of street asphalt we have repeated, first with a hollow prism made of window glass having faces about 15×20 cm. and refracting angle 30°, filled with resin-oil. When water or alcohol is placed in the hollow prism, no measurable fraction passes through. Another larger prism of solid resin, with 30° angle and faces 25 cm. square, was later constructed and gave good results; showing a deviation of about 18°. This prism has become broken, and one of a less brittle material, hard paraffine, is being made to take its place.

(6) *Interference of Two Reflected Waves.* This famous experiment of Boltzmann is readily performed. The necessary arrangement of apparatus is shown in fig. 2, *c*. In this case two mirrors M and M^1 are used. At first both are in the same plane and act as one large mirror, reflecting the radiation received from E to the receiver at R. Then M^1 is shifted back a few centimeters at a time and readings taken for each position. A figure showing the interference curve for this case was shown in the paper in *Phys. Rev.*, vol. 20, p. 271, and is reproduced here as fig. 4.

(7) *Refractive Index by Interposed-plate Method.* By inserting a plate of dielectric material in the path of one of the interfering beams in the last experiment, the position of nodes and loops will be shifted because the radiation moves with diminished velocity in the dielectric medium. From the amount of this displacement the refractive index is readily calculated. We have used paraffine


110
100
90
80
70
60
50
40
30
20
10
Fig. 4
" 5
Galv Deflections, in Mms.
Separation of Mirrors in Cms.
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34

plates for this experiment. Fig. 5 shows the displacement of the first two maxima caused by the insertion of a plate of paraffine 5, 3 cm. thick. From this curve it appears that the first maximum is shifted 2.9 cm. and the second 2.7 or a mean of 2.8 cm.

Then the refractive index $\dfrac{5{\cdot}3 + 2.8}{5{\cdot}3} = 1{,}56$

Another similar experiment gave $\dfrac{1.49 +}{\text{mean } 1.52}$

(8) *Diffraction Phenomena.* A variety of diffraction effects can be shown with such an apparatus, such as the spreading of the

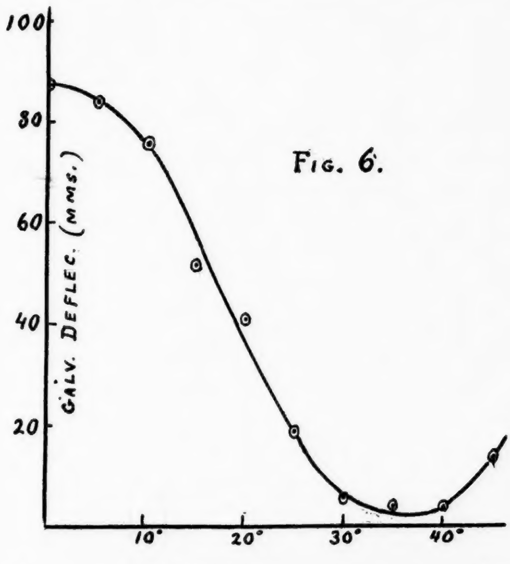


FIG. 6.

radiation after passing through a narrow aperture, the reflection of a larger amount of energy to a given receiver by a small plane mirror than by a considerably larger one diffraction bands by the use of a slit opening having a width suitably related to the wave-length employed, etc. Fig. 6 shows the first two "bright bands" with the intervening "dark band" obtained by the use of a slit, 17.6 cm. wide, interposed between exciter and receiver. In such experiments the receiver must be used without its usual

converging mirror or lens. It is admissible, however, to use a narrow metal strip placed one-quarter wave-length behind it as suggested by Righi in his book. We have used a narrow strip of sheet metal about 1.5 cm. wide. In fig. 6 abscissas give the angle in degrees through which the revolving receiver-arm was rotated from its central position and the ordinates the corresponding galvanometer deflection.

(9) *Amount of Reflected Energy Depended upon the Angle between Plane of Incidence and that of Vibration.* By revolving the cylindrical mirrors containing exciter and receiver, the proportion of radiation reflected by a surface of liquid is shown to be different with exciter and receiver in the relation shown in Fig. 2, *d* from that obtained in the position shown in Fig. 2, *e*. With water and an incident angle of 45° these ratios of reflected to incident energy are shown to be quite accurately such as are calculated from Fresnel's well-known formulas for reflection of polarized light, taking 8.95 as the refractive index of water for electric waves.

With alcohol the application of these formulæ to the results of a reflection experiment show a refractive index smaller than that found for longer waves. By this means anomalous dispersion for electric waves was discovered,[8] a discovery independently made by Drude a little later by an entirely different method.[9]

It is believed that the spectrometer form of mounting here described considerably facilitates the repetition of such classical experiments as are here described, strengthens the force of the optical analogies, and provides a suitable means for new research work.

Ohio State University.
April 28, 1909.

[7] H. Hertz, *Wied. Ann.*, 34, p. 610, '88.
[8] A. D. Cole, *Wied. Ann.*, 57, p. 310, '96.
[9] P. Drude, *Wied. Ann.*, 58, p. 1, 4, 18, '96.

THE DEVELOPMENT OF THE IDEA OF GLACIAL EROSION IN AMERICA.

FRANK CARNEY.

INTRODUCTION.

In this paper I give some brief citations, chronologically arranged, from such contributions of American students as represent a field study of glacial erosion, particularly in valleys; no attempt is made to trace the development of the cirque idea, or that of rock basins in mountainous areas. The literature contains numerous references, both incidental and extended, to the tendency of glacier ice to carve valleys; but until within the last decade these were disconnected observations representing, with few exceptions, local field experience if any at all, and in no individual case supplying data that could be correlated into convincing proof. Professor Davis summarized much of this literature up to 1882, giving many citations to show the development of the subject.[1]

What glacier ice, of either the Alpine or continental types, may have done in altering the surface it moved over has long been a matter of interest, sometimes disputatious interest; but the litera-

[1] W. M. Davis, "Glacial Erosion," *Proceedings of the Boston Society of Natural History*, vol. xxii, pp. 19–58, 1882. In the preceding volume of the *Proceedings*, pp. 336–45, Professor Davis gives a historical review of "The theory of the glacial origin of lakes." In vol. xxix, 1900, pp. 310–20, he reviews the "Previous writings on hanging valleys."

ture has generally grown less polemical with the increase of field knowledge. At the present time the belief in glacial erosion, locally even profound erosion, is almost universal.

It is many years since attention was first directed to the deepening of valleys as an evidence of glaciation. But for a long time no convincing proof was adduced. Perhaps the earliest observation approximating proof, and even this was not credited by many geologists, was King's description[2] of certain Cordilleran valleys which, passing downstream, change from a U-profile, ice-carved, to a V-profile, water-made. An appreciation of the distinction between the ice-modified and the water-made valley was of slow development. McGee[3] in 1883 briefly mentioned the relationship produced when ice makes a major valley wider, thus removing the terminal part of a tributary; but this intimation of the "hanging valley" condition apparently did not fix an impression in the minds of glacialists. In 1887 Russell gave a very accurate description of this relationship, but concluded that "the great inequality in the depth of the main glacial troughs and of their lateral branches is too great a work to be ascribed to the erosive power of ice."[4] The first description of an ice-produced discordance between a major and its tributary valley, given in sufficient detail and explicitness to merit acceptance, is that of Tarr in his "Lake Cayuga, a Rock Basin."[5]

1873 J. LECONTE.

Leconte says the fact that the Yosemite and other similar cañons in the Sierra Nevada "have been occupied by glaciers, makes it almost certain that they have been formed by this agency." "I must believe that all these deep perpendicular slots have been sawn out by the action of glaciers."[6]

[2] *Geological Exploration of the Fortieth Parallel*, vol. i, p. 478, 1873.

[3] W. J. McGee, *Proceedings of the American Association for the Advancement of Science*, p. 238, 1883.

[4] I. Russell, U. S. Geological Survey, *Eighth Annual Report*, part i, p. 352, 1889.

[5] *Bulletin of the Geological Society of America*, vol. v, pp. 339–56, 1894.

[6] Quoted from Davis, *Proceedings of the Boston Society of Natural History*, vol. xxii, p. 46, 1882. Leconte's statement appeared in *American Journal of Science*, vol. v, p. 339, 1873.

1878—CLARENCE KING.

One of King's conclusions from his study of glaciation in the Cordilleran section of the Fortieth Parallel Survey is the following: "There is not a particle of direct evidence, so far as I can see, to warrant the belief that these U-shaped cañons were given their peculiar form by other means than the actual ploughing erosion of glaciers; nor do the objections to this belief advanced by certain observers, based upon the moderate amount of detritus transported by the existing glacier-streams of the Alps, seem to be worthy of serious consideration, since the Alpine glaciers of the present day are at the best but the shrunken relics of the former system; and with vastly greater accumulation of snow in the ice period there is every reason to believe that the thickness, movement, and energy of the glacier must have been much greater, and that its power of abrasion would be correspondingly increased."[7]

1882—W. M. DAVIS.

In connection with Davis's arrangement of the evidence for and against glacial erosion, he makes the following comments: "It must be granted that the ice itself will suffer when pressed on its bed, and in spite of its long action will fail to produce much erosive change."[8]

"No sufficient reason has been given to show why the glaciers of the Italian slope of the Alps should be suddenly endowed near their ends with erosive power sufficient to cut out lakes 1000 to 2000 feet deep, while a little farther up stream their valleys were but slightly modified, as Ramsey himself claims."[9]

Professor Davis has since studied one of these valleys, and became convinced that ice had modified it; his discussion of ice-erosion in the Ticino valley, to be referred to later, is one of the great contributions to the subject.[10]

[7] *Loc. cit.*, p. 483.

[8] *Proceedings of the Boston Society of Natural History*, vol. xxii, p. 28.

[9] *Ibid.*, p. 53-54.

[10] *Appalachia*, "Glacial Erosion in the Valley of the Ticino," vol. ix, pp. 136–56, 1900.

1883—T. C. CHAMBERLIN.

The following statement is probably the first characterization of ice-work in the Finger lake region by a man of wide study and field experience in glacial geology:

"That these troughs were the preglacial channels of streams does not seem to me to admit of reasonable doubt; but that there was a *selection* and moulding by glacial corrasion seems equally clear; those channels that lay in the directions that would have been pursued had the ice moved on a uniform floor, being ground out wider, deeper, straighter, and smoother, while those in transverse directions were measurably filled and obscured."[11]

1892—D. F. LINCOLN.

After describing the surface features especially about Seneca and Cayuga lakes, he concludes: "The inference from these considerations is that the preglacial river which has been developed into Seneca lake must have occupied a level many hundreds of feet above the present bed of the lake."[12]

Following a descripiton of some valleys tributary to the Seneca valley, he says: "If these valleys, or any of them, had a preglacial existence and a rational connection with the lake valley, it would seem necessary to suppose that the bed of the latter then stood at an elevation 800 (?) feet higher than at present."[13]

1893—A. P. BRIGHAM.

Following a discussion of the Finger lakes, Brigham thus summarizes their origin: "To review briefly we suppose the basins to be a composite resultant of valley erosion, glacial scoop and drift barriers, with perhaps a slight element of orography."[14]

1894—R. S. TARR.

In a paper presented to the Geological Society of America in 1893, Tarr discusses the origin of the Finger lakes, particularly

[11] U. S. Geological Survey, *Third Annual Report*, p. 358.
[12] *American Journal of Science*, vol. xliv, p. 299.
[13] *Ibid.*, p. 300.
[14] *Bulletin of the American Geographical Society*, vol. xxv, p. 16.

the evidence of vigorous erosion in Cayuga valley. "In the Finger lake region the ice, moving from the northward, after entering the valley occupied by Lake Ontario, found its progress interfered with by the rising New York-Pennsylvanian plateau. Naturally the north-and-south valleys furnished lines of easiest escape, and naturally, also, the ice motion was here more powerful and the ice deeper. That the latter was true is proved by the fact that, even without the added depth due to ice erosion, these valleys were, at the beginning of the glacial invasion, at least 700 or 800 feet below the general upland level. This increase in thickness means, other things being favorable, an increase of erosive power."[15]

Tarr also gives detailed evidence showing the discordance of two valleys tributary to Cayuga valley; concerning one of these, Six-mile creek, he makes the following statement: "The north-and-south valley of Lake Cayuga is several hundred feet below it, and its depth has without question been caused by glacial erosion."[16]

1894—W. J. M'GEE.

After listing the characteristics of "glacial cañons," he says: "It follows that these features do not necessarily imply extensive glacial excavation or indicate that glaciers are superlatively energetic engines of erosion."[17]

1898—H. GANNETT.

Following a very complete description of glaciation in Lake Chelan valley, Gannett thus concludes: "There are therefore certain characteristics by which the gorge produced by glacial erosion may be distinguished from that produced by aqueous erosion. The glacial gorge has the shape of the capital letter U, while the water-worn gorge is a V-shaped notch. In a glacial gorge the spurs separating the tributaries have their ends blunted or planed off, while in a water-worn gorge they are sharp and angular. In a glacial gorge the tributaries enter the valley above its level, while in a water-worn gorge they commonly grade down

[15] *Bulletin of the Geological Society of America*, vol. v, p. 351.
[16] *Ibid.*, p. 350.
[17] *Journal of Geology*, vol. ii, p. 364.

to its level. A glacial gorge has an amphitheater at its head; a water-worn gorge has not."[18]

1899—A. P. BRIGHAM.

In an abstract of Brigham's paper "Glacial Erosion in the Aar valley" is this: "Below the lower Aar glacier, on the south side, a stream descends over the steep cliff face, carrying the waters of the upper Aar glacier. The lateral valley enters its principal some hundreds of feet above the floor of the latter, and thus is a typical case of the hanging valley. . . . . Similar hanging valleys enter from east and west at Innertkirchen."[19]

So far as I have been able to learn, this is the first published recognition by an American of "hanging valleys" in other lands.

1899—G. K. GILBERT.

In the discussion of Brigham's paper, Gilbert is reported thus: "He had been greatly impressed, years ago, by the magnitude of the glacial excavation indicated by such phenomena in the high Sierra, and last summer had found the coast of Alaska replete with similar evidence. After sailing for weeks through Alaskan fiords and observing scores of hanging valleys, he had come to regard their occurrence as diagnostic of the former extent of glaciation, and had used them with confidence as criteria for the discrimination of glaciated districts."[20]

1900—W. M. DAVIS

In discussing the "hanging valleys" of the Ticino he says: "The persistent association of this discordance with valleys that have been strongly glaciated points so conclusively to glacial erosion as its explanation that the doubts which I had long felt as to the ability of ice to erode deep valleys and basins—doubts which were not altogether dispelled by the arguments adduced by many glacialists regarding the U-shaped cross-section of ice-worn valleys, and by the form and distribution of lake basins—

[18] *National Geographic Magazine*, "Lake Chelan," vol. ix, p. 422.
[19] *Bulletin of the Geological Society of America*, vol. xi, p. 590.
[20] *Bulletin of the Geological Society of America*, vol. xi, p. 591, 1900.

were completely removed, and I came home with perhaps an over-ardent belief in the competence of glacial erosion, as is often the habit of the newly converted."[21]

Up to this time Davis had maintained a very conservative attitude when discussing glacial erosion; this conservatism appeared first in his "Basins of Glacial Erosion,"[22] and was explained in greater detail in later papers.[23]

1904—G. K. GILBERT.

Gilbert's studies in Alaska, on which was based his discussion of Brigham's paper at the Geological Society's meeting in 1899, were not published till this date. The following extracts make clear Gilbert's views on glacial erosion; his paper is one of the best contributions to the subject:

"The hanging valley is especially significant in two lines of physiographic interpretation. It is a conspicuous earmark of the former presence of glaciers; and it helps to a conception of the magnitude of Pleistocene glacial erosion."[24]

"The value of an earmark depends on the principle of exclusion: glaciation is the only physiographic process known to produce such forms."[25]

After discussing other processes that may result in mild cases of discordance between the grades of major and tributary streams, Gilbert says: "But despite all qualifications the hanging valley is the most important witness yet discovered to the magnitude of the work accomplished by the alpine glaciers of the Pleistocene."[26]

1905—H. L. FAIRCHILD.

That there is not complete unanimity in the interpretations based on field evidence is shown by the following which refers more particularly to the Finger lake valleys of New York:

[21] *Appalachia*, vol. ix, p. 139.

[22] *Proceedings of the Boston Society of Natural History*, vol. xxi, January, "On the Classification of Lake Basins," pp. 336–44, 1882.

[23] *Ibid.*, vol. xxii, May, 1882, "Glacial Erosion," pp. 19–58. U. S. Geological Survey, *18th Annual Report*, part ii, "Glacial Modification of Form and Drainage," pp. 179–81, 1898.

[24] *Harriman Alaska Expedition*, "Alaska," vol. iii, "Glaciers and Glaciation," p. 115.

[25] *Ibid.*, p. 116.

[26] *Ibid.*, p. 118.

"The most that can be reasonably claimed for ice-work is that it smoothed off the intervalley ridges and also the valley sides. The valleys are stream valleys, like valleys everywhere, and only slightly modified by ice action."

"Let us hope that assertions of the glacial origin or deepening of the Finger lake valleys (or any other valleys) will cease, and that former statements to that effect will be corrected."[27]

1906—R. S. TARR.

In discussing erosion in the Seneca valley, he says: "In this valley there is a general condition of remarkably perfect, broad, mature tributary valleys hanging several hundred feet above the lake level, at about the 900-foot contour. They are truncated by the straight, smooth, lower steepened slope of the main valley, so that they stand out prominently ,with open mouths, clearly discordant with the main valley, and about 1500 feet above the rock floor of the Seneca valley at Watkins."[28]

"When the hanging valleys of the Finger lake region were first recognized, and ice erosion proposed in explanation of them and of the main lake valleys,[29] there were few who accepted the conclusion advanced; but now the great majority of American physiographers accept the ice erosion explanation for this region, as well as for others."[30]

1906—W. M. DAVIS.

In connection with a discussion of "The present condition of the problem of glacial erosion," Davis states: "It has thus come to be believed by a number of observers that the glacial erosion of Piedmont lake basins must be extended to the over-deepening of the main mountain valleys far upstream from the lakes, and that the retrogressive glacial erosion of cirques carries with it the sapping and sharpening of the culminating ridges and peaks. The last named effect is truly not the direct work of ice, but it is so closely dependent upon glacial erosion that it should be included

[27] *Bulletin of the American Geological Society*, vol. xvi, "Ice Erosion Theory a Fallacy," p. 65.

[28] "Glacial Erosion in the Finger Lake Region," *Journal of Geology*, vol. xiv, p. 19.

[29] D. F. Lincoln, *American Journal of Science*, vol. xlix, pp. 290–93, 1892. R. S. Tarr, *Bulletin of the Geological Society of America*, vol. v, pp. 339–56, 1894.

[30] *The Popular Science Monthly*, vol. lxix, p. 391.

in any discussion of the sculpture of mountains by glacial agencies; just as the wearing of slopes and ridges by the weather goes with the erosion of valley bottoms by rivers."[31]

1907—R. S. TARR.

After a very detailed description of conditions observed in Alaska, concerning hanging valleys he says: "It is also true that this phenomenon is practically confined to regions of former glaciation. Together with the U-shaped valley, truncated spurs, and steepened main valley slopes, the condition of hanging valleys is reported not only from a wide area in Alaska and British Columbia, but in such other regions of former glaciation as the Sierra Nevada, the Rocky Mountains, the Finger lake valleys of central New York, the coast of Norway, the Alps, the Himalayas, and New Zealand."[32]

1908.

Following a field study of glaciation in Scotland, Tarr's conclusions are illustrated thus:

"Loch Ness is quite like one of the Alaskan "canals." It is remarkably straight, has perfect truncated spurs, numerous hanging valleys and many waterfalls along its shores. The height of the hanging valleys above the lake bed varies greatly and seems to be proportioned to the size of the valley as one would expect."

"The measure of glacial erosion in many instances is hundreds of feet and in places perhaps as much as a thousand feet, thus being comparable to the erosive activity of the Alaskan glaciers and the continental glaciers in the Finger lake region of central New York."

CONCLUSION.

The above quotations characterize the development of the idea of glacial erosion in this counrty; the list might be increased for many of the years as well as for the intervening periods. My aim has been to call attention only to the writings of men who have studied the subject most widely in the field.

[31] *The Scottish Geographical Magazine*, vol. xxii, "The Sculpture of Mountains by Glaciers," p. 1.

[32] "Glacial Erosion in Alaska," *The Popular Science Monthly*, vol. lxx, p. 113.

It is observed (1) that the present day idea of the amount of glacial erosion does not differ much from estimates written thirty years ago; (2) that the method of, and the several lines of evidence of, ice-work were slowly understood and analyzed; and (3) that the most convincing evidence of deep valley erosion, the hanging valley, was described fifteen years ago, while the truncated spur characteristic was later recognized.

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PRELIMINARY NOTES ON CINCINNATIAN FOSSILS.

Aug. F. Foerste.

The attempt to identify all the fossils found in Cincinnatian areas with the forms already described by various American and European writers has the disadvantage that it fails to account for the numerous varieties which may be distinguished when forms from different faunal provinces and from different horizons are subjected to more exact study. For purposes of stratigraphical studies the recognition of these varieties often is of the greatest value. In the following notes attention is called to a number of these varieties. Some of these appear to be sufficiently distinct to warrant their designation as species.

The following table, indicating the classification of the Cincinnatian strata in Ohio, now in use, will be of service in determining the vertical distribution of these fossils:

Formations.	*Beds.*
Richmond	Elkhorn Whitewater Liberty Waynesville Arnheim
Maysville	Mount Auburn Corryville Bellevue Fairmount Mount Hope
Eden	McMicken Southgate Economy
Utica	Fulton
Cynthiana	Nicholas Point Pleasant

In this classification the term Nicholas is used to designate the more coarse grained limestone section at the top of the Cynthiana formation. Southwest of Pleasant Valley, in Nicholas county, Ky., this limestone section is typically developed and has a thickness of 35 feet. Northward, along the Ohio river, its thickness decreases. The term Point Pleasant should be restricted to the lower part of the exposures at Point Pleasant, as intended by Professor Orton. That part of the river quarry beds at Cincinnati which contains *Trinucleus concentricus* does not belong to the Point Pleasant part of the Cynthiana formation. Formerly, when these beds were studied by Professor Orton, the lower part of the section at Point Pleasant was well exposed, considerable quarrying was carried on, and the rock from these lower layers was sent in large quantities to Cincinnati. At present, scarcely a trace of these quarries can be found.

The Fulton layer is the *Triarthrus becki* horizon, about 5 feet thick. The Eden was described by Orton, but formerly included also the Mount Hope beds, now referred to the Maysville. The Maysville includes the strata assigned by Orton to the Hill quarry beds. The Richmond corresponds to the Lebanon beds of Orton.

Protarea richmondensis, nom. nov.

Corallum incrusting, forming a layer usually about 2 millimeters in thickness, but sometimes equalling 3 or 4 millimeters; with about 4 corallites in a width of 5 millimeters. There are twelve septæ, with distinctly denticulate inner margins, which reach scarcely to one-half of the distance from the walls to the center of the calyces. At the base of the calyces the denticles or granules are arranged rather irregularly. In the specimen selected as a type the calyces are rather deep and the septæ distinct. In numerous other specimens, represented by figs. 9 *A*, *B*, on plate 1, the incrustation is thinner, the calyces are more shallow, the septæ are not so clearly defined except near the margin of the calyx, and the granules scattered over the base of the calyx are larger and more conspicuous. In none of the specimens have any clearly defined vertical tubules been found between the walls of the corallites.

Protarea richmondensis is common in the Whitewater beds, at Dayton, Ohio, where the type specimens were obtained, and it is

abundant at this horizon in Ohio and Indiana. It occurs also in the Liberty bed.

The type specimen of *Protarea vetusta* consists apparently of a succession of lamellæ vaiying from 1 to 2 millimeters in thickness, and more or less free from each other in places. There are usually about 5 corallites in a width of 5 millimeters, although sometimes the corallites are wider. The vertical tubules between the corallites are fairly distinct under a lens. The calyces are rather deep, and the septæ scarcely reach halfway to the center. *Protarea vetusta* was described from the Trenton at Watertown, New York.

Leptæna richmondensis, nom. nov.

(Plate IV, Figs. 10 A, B.)

The typical *Leptæna rhomboidalis* is regarded as an Upper Silurian form, originally found as an erratic specimen. The concentric wrinkles are deep, fairly continuous, and the intervening concentric folds are stronger.

The typical forms of *Leptæna richmondensis* were found in the upper part of the Waynesville bed, at Madison, Ind. It is a common fossil in the upper or Blanchester division of the Waynesville in Ohio and Indiana, and in the upper part of the Whitewater, but it occurs also in the intervening horizons and is found fairly low in the Waynesville, though not at the base. Compared with *Strophomena rhomboidalis*, the concentric wrinkles are usually less numerous, less deep, especially toward the beak, and the radiating plications are broader, with narrower intervening grooves. The shell is relatively wider, and in most specimens the top of the pedicel valve is comparatively flat.

This species was figured by Meek as *Strophomena rhomboidalis* var. *tenuistriata*. *Leptæna tenuistriata*, Sowerby, is figured as having much more numerous radiating striations, and a different form.

Leptæna richmondensis—precursor, var. nov.

(Plate IV, Fig. 11.)

In the Arnheim bed at Arnheim, and at numerous other localities in Ohio, and still more commonly at the same horizon in Kentucky, a variety of *Leptæna richmondensis* is found which varies chiefly in having the top of the pedicel valve more convex. The shell

usually is less strongly geniculate anteriorly, and the concentric wrinkles are less conspicuous, often becoming nearly obsolete toward the beak.

Strophomena maysvillensis, sp. nov.

(*Plate IV, Figs. 13 A, B.*)

The type specimen of *Strophomena planoconvexa*, preserved in the American Museum of Natural History in New York City, is labeled as coming from Cincinnati, Ohio. Shells of this type are found at Cincinnati at the base of the Fairmount, at the line of contact with the Mount Hope bed. They are characterized by the moderate convexity of the brachial valve and the slight convexity of the pedicel valve. The shell is either subquadrate in outline, with the hinge line only slightly longer than the width across the middle of the shell, or the length of the hinge line is distinctly greater and the outline is more nearly semicircular. The muscular markings on the interior of the pedicel valve are not deep, and the shell is only slightly thickened on the interior of this valve.

In the case of *Strophomena maysvillensis*, the types of which were found in the lower Fairmount at Maysville, Ky., the shell usually is larger and relatively longer. The convexity of the brachial valve is greater. The outline frequently is subtriangular, the brachial valve being more or less nasute anteriorly. The shell is distinctly, though not very strongly thickened along the anterior and lateral parts of the interior of the pedicel valve. This thickening does not reach the actual margin of the shell and is crossed by short though distinct radiating vascular markings. *Strophomena maysvillensis* is very abundant in the lower part of the Fairmount in all parts of Kentucky and in Adams county, Ohio. In the more western parts of Ohio and in Indiana, *Strophomena planoconvexa* is more common at this horizon. At Williamstown, Paint Lick, and various other localities in western Kentucky, *Strophomena maysvillensis* is common at the base of the Fairmount and *Strophomena planoconvexa* is found in smaller numbers at a higher horizon in the same bed. *Strophomena maysvillensis* makes its first appearance in the lower part of the Mount Hope in Kentucky, occurring at this horizon in by far the greater part of the Ordovician areas, especially east and along

the crest of the Cincinnati geanticline. *Strophomena maysvillensis* is always identified as *Strophomena planoconvexa* to which it is undoubtedly closely related. It is a much more abundant form than the latter and is believed to be sufficiently distinct from the same to warrant a separate name.

Typical specimens of *Strophomena planoconvexa* are figured by Meek in volume I of the *Ohio Paleontology*.

Strophomena concordensis, sp. nov.

(*Plate IV, Fig. 6 A. B.*)

At the top of the Arnheim bed is a bluish clay, often indurated and weathering into so-called nodular masses. This layer is characterized at numerous localities in the more southwestern counties in the Ordovician areas of Ohio by the presence of great numbers of *Strophomena concordensis*. This species occurs also at the same horizon at Concord, in Kentucky. Three miles south of Maysville, at the deep cut on the railroad, it occurs in limestone at the top of the Arnheim.

This species belongs to the same group as *Strophomena nutans*, but it is larger than typical specimens of that species, and the interior of the pedicel valve is never thickened as strongly or abruptly as in that form. The thickening of the interior of the pedicel valve, in fact, usually is only moderate, and is crossed by vascular markings which are more conspicuously parallel or moderately radiating along the anterior border than in any other species. The brachial valve usually is more or less nasute anteriorly, and the view of the shell from the side of the pedicel valve is more or less triangular. The convexity of the brachial valve varies considerably, but usually is rather strong. The flattened part of the valve extends only from 6 to 9 millimeters from the beak, but the rapid downward part of the curvature often does not begin until 15 millimeters from the hinge line. The radiating striations are of the type found in *Strophomena planumbona*. The types are from Concord, Ky.

Dalmanella emacerata, Hall.

Thirteenth Report, New York State Cabinet of Natural History, 1860, p. 121.

No illustrations accompany the original description. In the

Fifteenth Report of the same series of publications, 1862, figs. 1, 2 and 3 on plate 2 are intended to illustrate this species. These figures differ considerably in outline; hence, fig. 1 is taken as the type. It evidently represents a brachial valve having a subquadrate outline, with a length equalling about three-fourths of the width. The type from which this figure was prepared is preserved in the American Museum of Natural History, in New York City. It evidently belongs to the coarsely striated forms usually listed under *Dalmanella emacerata*, and the coarseness of the striations is well represented by fig. 1, on plate 2 of the Fifteenth Report. In these forms about 8 to 10 striations occupy a width of 5 millimeters along the anterior margin of shells having a width of 20 millimeters.

Geological position. The type was received from Mr. Carley, and came from the Cincinnati Group, at Cincinnati, Ohio. The exact horizon from which the type came is unknown. Specimens having the same characteristics as the type were collected by Bassler and Albers in the *Triarthrus becki* horizon, or Fulton layer, at the base of the Eden formation. This Fulton layer is approximately equivalent to the Utica of New York. Specimens from this horizon are here regarded as typical. Specimens not distinguishable from the typical form have been received from various collectors from elevations of 60, 75 and 150 feet above the base of the Eden. This would extend its range into the Lower and Middle Eden. Further collecting from definite horizons is necessary. None of the forms figured by Meek as *Orthis emacerata* belong to this species.

Dalmanella emacerata—filosa.

(*Plate IV, Fig. 1*)

Some of the specimens referred to *Dalmanella emacerata* differ from the type in having considerably finer and more numerous striations. The specimen here figured, magnified 1.6 diameters, collected by Bassler from the *Triarthrus becki* horizon at Cincinnati, has 14 to 16 striations in a width of 5 millimeters. A similar specimen was found 150 feet above the base of the Eden. Until additional material has been collected it must remain doubtful whether these more finely striated forms should receive any separate designation.

Dalmanella bassleri, sp. nov.

A species of *Dalmanella* occurs near the base of the exposures at Carnestown, Ky., which appears to have been distinctly more robust and more convex than *Dalmanella emacerata* since the pedicel valves are always distinctly, though not strongly, convex, and the brachial valves, though nearly flat, are sufficiently convex toward the beak to make the shallow median depression fairly distinct. The radiating striations are numerous but appear coarser, and their fasciculate arrangement is more evident. *Dalmanella emacerata*, on the contrary, usually appears only in the form of very much flattened shells, even when forming the tops of layers of limestone.

The species from the lower beds at Carnestown often attain a large size. Some specimens 27 mm. wide, 22 mm. long, and about 4 mm. in depth are known. Striations corresponding to the radiating striations marking the exterior, are found on the interior of both valves, even where the muscular impressions should appear. The muscular area of the pedicel valve is distinctly limited postero-laterally by the ridges which are a continuation of the short plates supporting the short hinge teeth. Anteriorly these ridges soon become indistinct. An angulation in these ridges often indicates the point of demarcation between the anterior and posterior adductor impressions. There is no trace of muscular impressions in the brachial valve. A low median elevation divides the posterior part of the area where these impressions should occur. Posteriorly this elevation fills the lower part of the space between the short crural plates, and bears at its posterior end the short cardinal process, more or less trilobate posteriorly in some specimens.

At Carnestown, Ky., this species occurs associated with *Callopora multitabulata* and *Strophomena trentonensis*, between 8 and 15 feet above the Ohio river. At South Moscow, it is abundant immediately above the *Callopora multitabulata* horizon, about 11 feet above the Ohio river. It occurs at about the same horizon north of Butler, and at Parks Hill. East of Carnestown, it appears to occur in the lower part of the Cynthiana formation, and it is fairly common east of Florence, Indiana, opposite Warsaw. Farther south, it appears to occur in the Wilmore bed, belonging to the so-called Trenton of Kentucky. The Carnestown specimens appear to belong near the top of the Paris bed, forming the top of

this so-called Trenton. The chief interest of this species in the present connection is its presence apparently in the lower part of the Cynthiana division of the Cincinnatian in some of the localities along the Ohio river. Named in honor of Ray S. Bassler.

Dalmanella breviculus, nov. sp.

In the Middle Eden beds at Cincinnati, Ohio, flat finely striated forms of *Dalmanella* occur, with 14 striations in a width of 5 millimeters in specimens 20 millimeters wide. The ratio of the length to the width often is as low as two-thirds. The result is a semicircular outline, readily distinguished from the subquadrate outline of *Dalmanella emacerata-filosa*, which also has fine striations. The pedicel valve is moderately convex, especially anteriorly, the most convex part, one-third of the length of the shell from the beak, rising 3 millimeters above the margin of the valve. There is a shallow median depression in the brachial valve.

Geological position. The types came from the Middle Eden beds at Cincinnati, Ohio. It occurs at the same horizon at Vevay, Indiana. Somewhat similar forms have been secured by Cincinnati collectors about 60 feet above the base of the Eden. The types from the Middle Eden beds, at Cincinnati, will be illustrated later. In the meantime, fig. 2 on plate 2 of the *Fifteenth Report*, New York State Cabinet of Natural History, will serve as an excellent illustration of the species. It is not known, however, whether this specimen is still in existence, or from what horizon it came. Hence it is considered inadvisable to use the specimen there figured as a type.

Dalmanella fairmountensis, nov. sp.

(*Plate IV, Figs. 2 A, B, C.*)

Shell small, averaging 15 millimeters in width, but sometimes attaining a width of 18 millimeters. Shell usually wider posterior to the middle, the lateral edges more or less straightened, but converging anteriorly, suggesting a symmetrical trapezoidal rather than semicircular outline; however, shells with subquadrangular and with semicircular outlines also exist.

Pedicel valve with sides somewhat flattened and sloping away from a more or less distinct median axis of elevation; the latter

is most distinct posteriorly but frequently reaches the anterior margin. Lateral margins of the muscular area divergent as far as the anterior end of the exterior pair of diductor impressions, and then convergent with a sinuous curvature as far as the anterior margin of the second pair, between which there is a strongly reëntrant angle as far as the anterior edge of the adductor impressions. The adductor impressions are oblong and occupy about one-fifth of the width of the muscular area.

Brachial valve flattened toward the lateral margins, but slightly convex on each side of the distinct median depression; the latter is narrow near the beak, but widens anteriorly, and produces a distinct abrupt curvature in the outline of the shell when viewed from the anterior side. The strong and rather wide median elevation separating the adductor scars broadens posteriorly between the crural plates, and supports the cardinal process. The latter is divided by a median slit, and often is fairly conspicuous.

Geological position. Fairmount beds. The types are from the quarries in the southwestern part of Hamilton, Ohio, where it is abundant. It is much less common at New Trenton, and half a mile east of Dillsboro Station, in Indiana. It appears to have a very restricted geographical range.

Fig. 1*d* on plate 8 of volume i of the *Ohio Paleontology* appears to represent this species.

Dalmanella multisecta, Meek.

This species ranges throughout the Eden formation, into the Mount Hope and the base of the Fairmount beds. Two extremes have been figured by Meek. The type specimens, illustrated by figs. 3*a* to 3*d* on plate 8 of volume i of the *Ohio Paleontology*, have finer striæ, a more circular outline, and a more even convexity of the pedicel valve. The other extreme is illustrated by figs. 1*a* to 1*c* on the same plate, and is characterized by somewhat coarser striations, a more triangular outline, and a more angular convexity of the pedicel valve, best seen when viewed from the same side as the hinge area.

Dalmanella jugosa, James.

(Plate IV, Figs. 16 A, 16 B.)

Paleontologist, no. 4, p. 31, 1879.

This species was described by James from the upper beds of the Cincinnati Group, an expression which he used for the strata now included in the Richmond formation. His description includes two forms: one with a quite sharp mesial ridge on the pedicel valve, usually occurring low in the Waynesville bed in Clinton and neighboring counties in Ohio; and another with this mesial ridge but little conspicuous above the regular prominent convexity. Only the latter is abundant in the Richmond group over a wide area, and the latter is here regarded as the type. It is abundant in the Waynesville bed, especially below the Blanchester division of this bed, both in Ohio and Indiana. Very typical specimens occur at Oxford and Clarksville, Ohio.

Dalmanella meeki, Miller.

Cincinnati Quarterly Journal of Science, vol. 2, p. 20, 1875.

Miller, in describing *Orthis meeki*, not only copies verbatim the description of *Orthis emacerata* as identified by Meek in volume i of the *Ohio Paleontology*, but specifically states that figs. 2*a* to 2*g* on plate 8 of that volume are regarded as illustrating typical specimens of *Orthis meeki*. Therefore, the specimens figured by Meek must be considered as the types of *Orthis meeki*. Unfortunately, these types can not be found.

Meek states that the typical form of *Orthis emacerata*, as identified by him, occurred at an elevation of 250 feet above the Ohio river, at Cincinnati, and on other pages of the same volume he states that *Orthis multisecta* ranges up to 200 feet above low water mark, and that *Orthis bellula*, *Orthis ella*, *Orthis fissicosta*, and *Orthis plicatella* occur at 300 feet. There is nothing to indicate that the form he considered typical was at all common or had any considerable vertical range, although he had other specimens, differing very little, from higher horizons, both at Cincinnati, and in Butler county. This suggests that some large form of *Orthis multisecta* may have formed the basis of Meek's statement. This form should occur somewhere near the top of the Eden, and need not be common.

The specimen illustrated by figs. *2a*, *2b*, *2e*, *2f* and *2g* may represent the large form of *Dalmanella multisecta*, if such a form exists; but, as far as may be determined from the figures, it appears to have been a good specimen of *Dalmanella jugosa*, from the Waynesville bed. While there may be large specimens of *Dalmanella multisecta*, in the Upper Eden, it does not seem likely that any of these would have dorsal valves as strongly convex as the one represented by figs. *2e* and *2f*.

Miller regarded Meek's statement concerning the horizon at which the specimens illustrated by figs. *2a* to *2g* were found as in error, and expressed the belief that these specimens came from Hamilton, in Butler county, Ohio. In fact, he states that the typical specimens *2a* to *2g* are quite common at the quarries in Hamilton, Butler county, associated with *Orthis ella*, *Orthis bellula*, *Orthis fissicosta*, *Orthis plicatella*, *Orthis sinuata*, *Glyptocrinus decadactylus*, and other species indicative of a range from 300 to 400 feet above low water mark, at Cincinnati; in other words, in the Fairmount beds. Since only the form here described as *Dalmanella fairmountensis* is common at this horizon at Hamilton, J. Mickleborough and A. G. Wetherby in their catalogue of *Lower Silurian Fossils of the Cincinnati* group, published in 1878, list *Orthis meeki* as a variety of *Orthis emacerata;* and James, in 1879, in the *Supplement* to his catalogue, regards it merely as a synonym of *Orthis emacerata*. That this is in error is shown by Miller, in his description of *Orthis multisecta*, in the same volume of the *Cincinnati Quarterly Journal of Science*, where he states of *Orthis multisecta*: "it is abundant at nearly all exposures from low water mark, at Cincinnati, to 250 feet above; after this, as we ascend in the strata the form which I have called *Orthis meeki* prevails in its stead. It would be impossible to determine where one form begins and the other ends, as they clearly intermingle, and leave the constantly recurring impression that they are not specifically distinct." Under his description of *Orthis meeki*, on the contrary, he states that this species can be readily distinguished from *Orthis emacerata*. That Miller was familiar with *Dalmanella emacerata* is shown by his statements that this species was found on Columbia avenue and on the Torrence road, 160 feet above low water mark, and was not known over 200 feet above low water mark, at Cincinnati. This is the Middle Eden horizon, at which *Dalmanella emacerata* is rather widely distributed.

Since *Dalmanella fairmountensis* might easily be regarded as a small form of *Dalmanella emacerata*, but scarcely as closely related to *Dalmanella multisecta*, this identification of the Fairmount species as *Dalmanella meeki* must be abandoned, notwithstanding the horizon assigned to it by Meek. From this it seems evident that Miller himself may have been in error in assigning his specimens of *Dalmanella meeki* to the Fairmount horizon. How he could possibly be in error regarding such a common form as *Dalmanella fairmountensis* at a locality so frequently visited by Cincinnati collectors as Hamilton, Ohio, it is difficult to understand. Possibly the fact that *Dalmanella jugosa* is common on the crests of all the hill ridges encircling Hamilton on the west, within three miles of the center of the city, and that the tops of the hills at the quarries within the boundaries of Hamilton are of Fairmount age, may have led to the confusion, especially in view of the fact that the intermediate region is poor collecting ground, and that the *Platystrophia lynx* horizon in the Mount Auburn bed is poorly developed there. It must be remembered that the subdivisions of the Cincinnatian, as established by Nickles, were not known at that time. In fact, the Catalogue published by Ulrich in 1880, the first serious attempt to work out the horizons of the various fossils, is full of errors natural to such a first attempt, when collectors often were not very communicative as to the source of their fossils.

Among the various reasons which have led to the identification of *Dalmanella meeki* as the Fairmount species is Miller's statement, following the republication of Meek's description, that *Orthis meeki* is smaller than *Orthis emacerata*. Now as a matter of fact, the great majority of specimens of *Orthis jugosa* occurring on the hill ridges west of Hamilton are distinctly smaller than most of the specimens of *Dalmanella emacerata* which I have collected from the Middle Eden, and if the remainder of Miller's comparison of *Orthis meeki* with *Orthis emacerata* be read, it must be conceded that this comparison is fully as applicable to *Orthis jugosa* as to *Orthis fairmountensis*, especially when it is stated that the striæ of *Orthis meeki* are not so fine.

On the other hand, how could Mickleborough, Wetherby, and James be mistaken as to the form described by Miller, when all lived in the same town and met frequently.

From a consideration of the preceding facts I have been led to

the conclusion that Miller probably had specimens of *Dalmanella jugosa* at hand when he described *Orthis meeki*, but this is rendered uncertain by his assigning the species to the Fairmount horizon, and by the fact that three collectors from the same town within 4 years of the first description of this species actually referred *Orthis meeki* to *Orthis emacerata*, which would be the natural affiliation of the Fairmount species. However, no matter what Miller intended to do, his republication of Meek's description of *Orthis emacerata* and his reference to figs. 2*a* to 2*g* as illustrations of typical specimens, would make Meek's types also the types of *Orthis meeki*. Meek's types can not be found. However, as long as no careful search has been made in the top of the Eden formation, or in the overlying strata, including the Fairmount, for large *Dalmanellas* which might have been used as a basis for Meek's description, and possibly also for his figures, the use of this term must remain uncertain. Large specimens of *Dalmanella* sent to me several years ago by Mr. John M. Nickles, and labeled as coming from the upper Eden, suggest that such forms may exist. Hence, for the present, the term *Dalmanella jugosa* seems preferable, until the identity of the specimens described by Meek has been established beyond all question.

Dalmanella (**Bathycœlia**) **bellula,** Meek.

Dalmanella bellula belongs to the group of *Dalmanellas*, typified by *Dalmanella subæquata*, Conrad, in which the brachial valve is strongly convex, and the median depression is absent or only faintly indicated. This group appears to have had a phylogenetic history distinct from the group typified by *Dalmanella testudinaria*. It ranges from the Stones river to the Devonian. For the species included in this group, the term *Bathycœlia* is proposed as a subgeneric term.

Plectorthis fissicosta, Hall.

(*Plate IV, Figs. 5 A, B.*)

The illustrations of the type specimen of *Orthis fissicosta*, preserved in the American Museum of Natural History, as presented in fig. 7, on plate 32 of volume i of the *Paleontology of New York*, is not sufficiently definite for present needs of paleontological study. For this reason, photoengraved illustrations, one of them

magnified, are herewith presented. These illustrations indicate that *Orthis fissicosta* is more nearly related to *Orthis triplicatella*, Meek, than at first supposed. In fact, *Orthis triplicatella* can scarcely be regarded as a distinct variety of *Orthis fissicosta*, Hall.

Plectorthis (Eridorthis) nicklesi, nov. sp.

(*Plate IV, Figs. 3 A, B, C, D.*)

Shell small, usually about 15 millimeters in width, and 11 millimeters in length, and with an estimated thickness varying between 3.5 and 4.5 millimeters.

The initial stages of the convex brachial valve begin with a median groove bordered by the first radiating plications. This median groove remains a distinctive feature of the mature shell and may be traced to a distance of 4 millimeters from the beak. Anterior to this, the various plications intercalated along the middle of the shell rise so as to form a median fold, often very distinct anteriorly, but sometimes only very slightly elevated. Each of the primary plications bordering immediately upon the initial median groove bifurcates very near the beak, and the inner one of these bifurcations usually forms part of the median fold anteriorly. Four or five of the plications forming the fold originate at or posterior to the middle of the shell. Sometimes several smaller plications are added anteriorly. Ten or eleven lateral plications originate on each side of the median fold posterior to the middle and to these plications others are added before reaching the margin. The result is a rather finely plicated shell. Distinct and rather distant concentric striations are easily recognized under a lens. Shell thin, with the radiating plications showing distinctly on the interior surface, and practically with no indication of the muscular scars. The median elevation which usually separates these scars, however, is plainly indicated. Posteriorly, it fills the lower part of the space between the crural plates, and supports the thin cardinal process, which thickens moderately anteriorly.

Pedicel valve beginning with a median plication which is not more prominent than the lateral primary plications. Beginning near the middle of the valve, the median part of the shell becomes depressed anteriorly, and forms a rather shallow sinus, including a smaller number of plications than those found on the median fold of the brachial valve. The pedicel valve usually is more

convex than the brachial, owing to the much greater height of the hinge area. Hinge teeth projecting but slightly beyond the cardinal line, supported by vertical plates uniting with the posterior part of the lateral border of the muscular area. Muscular area about 3.3 mm. in width and 4 mm. in length in a shell having a total length of 11 millimeters. The muscular area rests upon a callosity thickening anteriorly to a height of about three-fourths of a millimeter above the general surface of the interior of the valve. The muscular scar is divided lengthwise by two low striations into three divisions of which the middle one is slightly narrower, but projects a little farther anteriorly. In one case a narrow median striation is found along the central division of the muscular area. It is assumed that the lateral divisions correspond to the diductor muscular scars. How much of the middle division corresponds to the adductor scars is unknown.

Geological position. The types come from the Lower Eden, at Roger's Gap, Ky. They occur from this locality northward as far as Sadieville. Southeastward they may be traced as far as Hutchison in southwestern Bourbon county, and Riverside, in the southern part of Clark county. Along the Ohio river they have been traced from Cincinnati to Higginsport. They appear to be confined to the lower part of the Lower Eden.

The deep median groove in the initial stages of the brachial valve, and the well marked fold and sinus anteriorly on the two valves, produce a form quite distinct from the more typical forms referred to *Plectorthis.* For the group of shells typified by *Plectorthis nicklesi* and *Plectorthis rogersensis*, the subgeneric term *Eridorthis* is proposed.

Plectorthis (Eridorthis) rogersensis, nov. sp.

(*Plate IV, Figs. 4 A, B.*)

A second form, evidently so closely related to *Plectorthis nicklesi* as to be possibly only a variety, occurs at the same localities as that species, and at the same horizon. It appears to be more common at Roger's Gap than *Plectorthis nicklesi*, and differs chiefly in having distinctly fewer radiating plications, on the sinus, in the fold, and also laterally. The plications are broader, and the concentric striations are stronger and more distant.

Hebertella alveata, nom. nov.

(*Plate IV, Figs. 8 A, B.*)

The types are greatly prolonged at the hinge line, and have a distinct and broad median depression along the brachial valve, extending from the beak to the anterior margin of the shell. Another form, apparently merging into the former, but narrower, with the hinge line often slightly less than the width of the shell across the middle, and with the brachial valve often more convex from front to rear, occurs frequently in the Whitewater beds of Richmond, Indiana. The latter form may be called *Hebertella alveata-richmondensis*, and is mentioned only because at some localities it is common while the form with extended hinge line may be absent.

Shells having the form of *Hebertella alveolata* begin their existence in the Liberty bed, and are widely distributed in the Whitewater beds, in Ohio and Indiana. They were erroneously identified by Meek as *Orthis occidentalis*.

In *Hebertella occidentalis*, Hall, from the Maysville formation, as represented by the types preserved in the American Museum of Natural History in New York City, where they are labelled as coming from Cincinnati, Ohio, there is only a faint median depression near the beak of the brachial valve, disappearing anteriorly. This depression is scarcely discernible unless the shell is held in a favorable light. Judging from the types of *Orthis sinuata*, preserved in the same museum, the latter is only a more coarsely plicate form of *Orthis occidentalis*.

Austinella scovillei, Miller.

Journal, Cincinnati Society of Natural History, vol. 5, p. 40, 1882.

Dinorthis scovillei belongs to a group of species typified by *Orthis kankakensis*, McChesney and including also *Orthis whitfieldi*, N. H. Winchell. *Orthis kankakensis* and *Orthis whitfieldi* were listed by Hall, Clarke, and Schuchert under *Plectorthis*. *Orthis scovillei* was listed by them under *Hebertella*, but was placed by Nickles under *Dinorthis*.

The distinctly quadrate muscular scar of the ventral valve in these species suggests affinities with *Dinorthis*. This view is

favored also by the presence of vascular markings leaving the antero-lateral angles of the scars, and branching antero-laterally. These vascular markings are better shown by *Orthis scovillei*, but the most strongly developed part, nearest the muscular scars, is present also in the other species. This group differs from typical *Dinorthis*, however, in the form of the adductor scars, which are linear, extending to the anterior margin of the muscular area, as in typical *Hebertella*. In width, these adductor scars equal almost one-third of the width of the entire muscular area. While showing affinities to both *Dinorthis* and *Hebertella*, this group is sufficiently distinct from both to merit at least a subgeneric term, and the term *Austinella* is proposed, in honor of Dr. George M. Austin, to whom most of our knowledge of the vertical distribution of the Richmond brachiopoda of Ohio is due.

Platystrophia ponderosa, nom. nov.

(*Plate IV, Fig. 14.*)

The type specimen, here figured, came from the Bellevue bed at Madison, Indiana, where it is very abundant. In fact, this species is very abundant in the Bellevue bed in southern Indiana and Ohio, and in most parts of Kentucky. It is not infrequent in the upper part of the Fairmount bed at Maysville and elsewhere in Kentucky. At Maysville, and four miles west of Richmond, in Kentucky, a direct precursor of this species, almost of the same size, occurs in the upper part of the Middle Eden. It is much less common in the Corryville bed than in the Bellevue, but becomes common again in the Mount Auburn bed. It occurs commonly in the Arnheim bed in Kentucky, and in Bullitt county it is known even from the base of the Waynesville.

Platystrophia ponderosa is characterized by its large size, thick valves, and quadrangular outline; the brachial valve has a prominent, though rather rounded, median fold, usually occupied by four plications. The sinus on the pedicel valve is broad, not very deep, and is occupied usually by three plications. The lateral plications vary between 7 and 9. Sometimes 6 plications occupy the median fold. The shell is greatly thickened interiorly, especially around the deep muscular scar in the pedicel valve.

In form this shell appears to agree more nearly with *Platystrophia biforata*, Schlotheim, but Von Buch, who saw the type

specimen in the Royal Museum at Berlin, in 1838, stated that this specimen had 5 plications in the sinus. Moreover, in our specimens the sinus and fold appear respectively less deep and elevated, and the bounding surfaces less vertical than in specimens referred to *Platystrophia biforata* by Curt Gagel. Unfortunately very different forms have been referred to *Platystrophia biforata* at various times. The type of that species appears never to have been figured, and it seems to have been lost.

Platystrophia ponderosa—auburnensis, nom. nov.

(*Plate IV, Fig. 15.*)

The type of this variety was found in the Mount Auburn bed at Lebanon, Ohio. The variety is fairly common at the Mount Auburn horizon at Cincinnati, and at other localities in Ohio. It may be regarded as characteristic of that horizon, but does not exist there to the exclusion of *Platystrophia ponderosa*, of which it may be regarded as a more gerontic form. It is more globose, and has a distinctly shorter hinge line. As a rule the shell is narrower and the number of lateral plications is less, sometimes not exceeding 5 or 6, becoming obsolete toward the postero-lateral angles.

This variety appears to be closely related to *Platystrophia lynx*, Eichwald, as identified and figured by Curt Gagel. Eichwald describes the median fold of *Platystrophia lynx* as having 4 grooves so that there should be 5 plications. Von Buch states regarding the same species that it had 4 plications in the sinus and on the fold, and 9 plications on each side. The specimens figured by Curt Gagel as *Platystrophia lynx* are relatively longer, the fold and sinus are more abrupt, and the lateral plications are more numerous, and more distinct toward the postero-lateral angles than in the forms selected as types of *Platystrophia ponderosa-auburnensis*.

It is possible that the specimens figured by Meek as *Platystrophia lynx*, in volume i of the *Ohio Paleontology*, were obtained from the Mount Auburn horizon, but they do not have as short a hinge line as the variety here illustrated, they are less globose, and the lateral plications are more numerous and more distinct postero-laterally.

The type of *Platystrophia lynx* as described by Eichwald ap-

pears to have been lost, and no figuie was published of this type specimen.

Cyclocoelia sordida, Hall.

Paleontology of New York, vol. i, p. 148, 1847.

The type of *Orthis sordida*, preserved in the American Museum of Natural History, in New York City, is evidently a Cincinnatian species belonging to the group of *Orthis ella*. It has 21 primary plications, and one intercalated plication. In the description of *Orthis ella*, 15 to 20 simple plications are mentioned. The types of *Orthis elia* preserved in the American Museum of Natural History include 5 entire specimens. Of these three have 18 or 19 plications, a fourth specimen has 21 plications, and the fifth specimen, not typical according to the description, has 27 plications of which between 5 and 7 plications evidently are intercalated within 1 millimeter from the beak. *Orthis ella* does not form even a variety of *Orthis sordida*, but should be regarded as an exact synonym.

The pedicel valve has an open triangular delthyrium; the hinge teeth are supported by diverging vertical plates which extend only about two millimeters from the beak in case of shells having a length of 7 millimeters. Cross sections do not indicate the presence of any muscular area. No distinct hinge area is present. The brachial valve possesses two crural plates which appear to be rather broad and to terminate anteriorly in a point. A sharp median striation extends forward to almost 3 millimeters from the beak. No loops or spiralia were detected. One specimen appeared to show a short narrow cardinal process. All other specimens failed to give any definite information. The exact definition of this genus awaits further study. The term *Cyclocœlia* therefore can not be said to have established value, but it will serve at least to remove to a separate group a number of species, including *Orthis sectostriata*, Ulrich, which at present have no distinctive designation.

Rhynchotrema dentata—arnheimensis, var. nov.

(*Plate IV, Fig. 12.*)

The type of *Rhynchotrema dentata* was obtained from the Richmond group in some part of Ohio or Indiana. It appears to be an immature specimen of the Whitewater form, as found at Rich-

mond, Indiana, and elsewhere at the same horizon. It occurs also in the upper or Blanchester division of the Waynesville bed, and occasionally in the Liberty.

In the Arnheim bed, in many parts of Kentucky, at Goodlettsville, Newsom, and Clifton, in Tennessee, also at Arnheim, and a few other localities in Ohio, a variety of this species occurs which usually is larger, more triangular, less globose, especially along the posterior half of the shell, and usually with distinctly sharper, more angular plications. The degree of angularity attained by these specimens is not very well shown by the accompanying figure of a specimen from Arnheim, Ohio. The more typical specimens are abundant in the Arnheim bed south of the bridge across Salt river on the road from Mount Washington to Bardstown, in Kentucky.

Ceraurus miseneri, nov. sp.

(*Plate IV, Fig. 7 A, B.*)

The type specimen was found in the Whitewater bed at Richmond, Indiana. A fragment retaining the glabella and fixed cheeks was found at the same horizon at Dayton, Ohio.

The glabella widens from 5.6 at the rear to almost 9 millimeters anteriorly. There are three pairs of globular lateral lobes of which the posterior pair is distinctly separated from the median part of the glabella. The frontal lobe of the glabella, with its lateral extremities, has a semicircular outline. The occipital groove and its extension across the fixed cheeks is distinct. The eyes are prominent. The genal angles are blunt and rounded. The anterior outline of the head is moderately trilobate, owing to the reëntrant angles which are in line with the diverging sides of the glabella. Surface marked by coarse but rather distant granules.

Pleuræ with a large node posterior to the pleural groove, near the middle division of the thorax. Another large node is located at the point where the pleura is deflected downward. A third and smaller node is found between these two, but nearer the anterior margin.

PLATE IV.

Fig. 1. *Dalmanella emacerata-filosa*. Pedicel valve, enlarged 1.6 diameters.

Fig. 2. *Dalmanella fairmountensis*. All figures enlarged about 1.1 diameters. *A*, *B*, pedicel valves; *C*, brachial valve.

Fig. 3. *Plectorthis* (*Eridorthis*) *nicklesi*. *A*, *C*, pedicel valves; *B*, *D*, brachial valves.

Fig. 4. *Plectorthis* (*Eridorthis*) *rogersensis*. *A*, pedicel valve; *B*, brachial valve.

Fig. 5. *Plectorthis fissicosta*, Hall. Type. *A*, brachial valve; *B*, the same enlarged 1.6 diameters.

Fig. 6. *Strophomena concordensis*. *A*, interior of pedicel valve; *B*, brachial valve.

Fig. 7. *Ceraurus miseneri*. *A*, glabella and fixed cheeks; *B*, cephalon.

Fig. 8. *Hebertella alveata*. *A*, brachial valve; *B*, pedicel valve.

Fig. 8-*C*. *Hebertella alveata-richmondensis*. Brachial valve of a specimen which is not the type.

Fig. 9. *Protarea richmondensis*. *A*, on *Strophomena planumbona*; *B*, the same enlarged 1.6 diameters.

Fig. 10. *Leptæna richmondensis*. *A*, pedicel valve; *B*, brachial valve.

Fig. 11. *Leptæna richmondensis-precursor*. Pedicel valve.

Fig. 12. *Rhynchotrema dentata-arnheimensis*. Brachial valve.

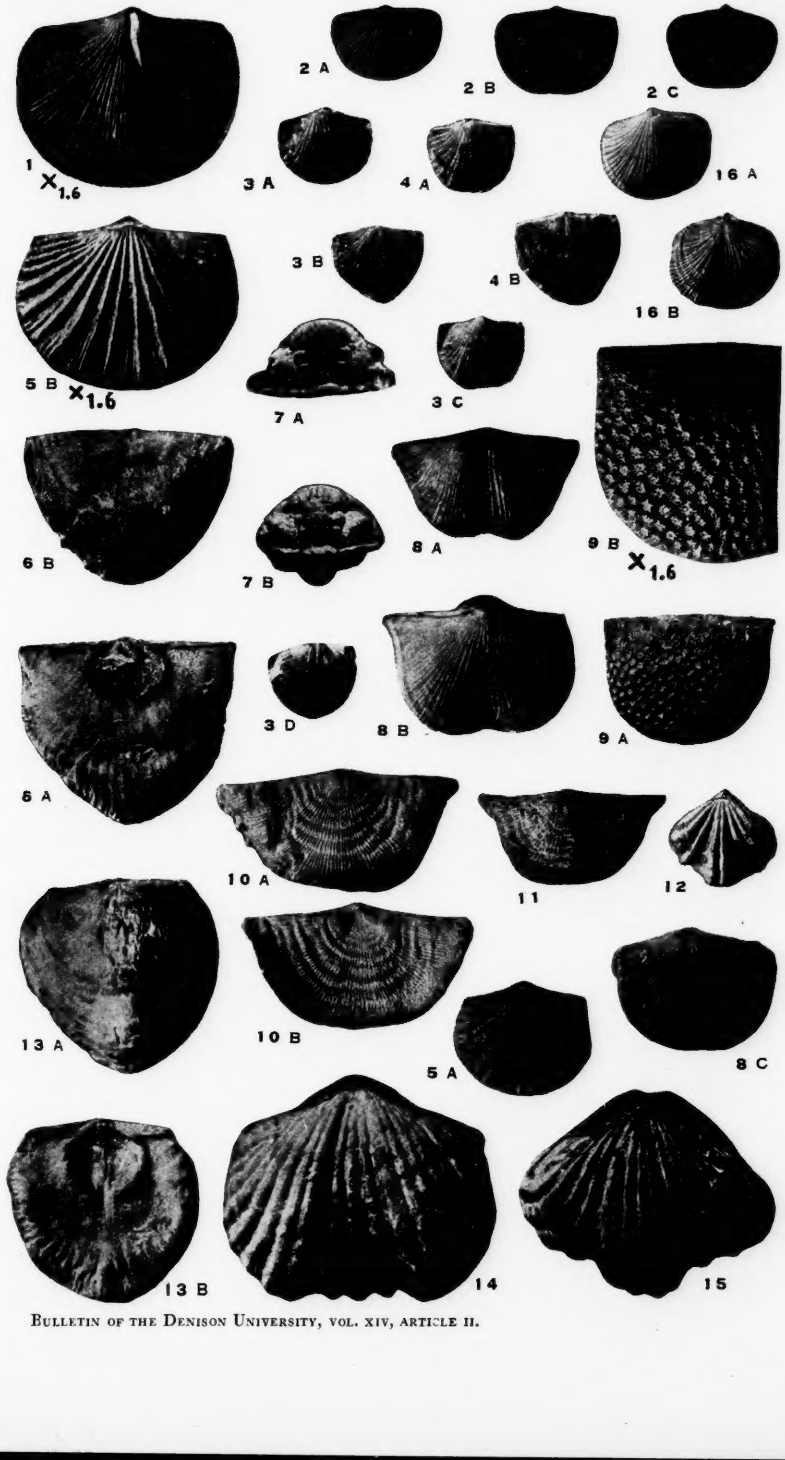
Fig. 13. *Strophomena maysvillensis*. *A*, Brachial valve; *B*, pedicel valve.

Fig. 14. *Platystrophia ponderosa*. Pedicel valve.

Fig. 15. *Platystrophia ponderosa-auburnensis*. Brachial view.

Fig. 16. *Dalmanella jugosa*. *A*, pedicel valve; *B*, brachial valve.

PLATE IV.


1 ×1.6
2 A
2 B
2 C
3 A
4 A
16 A
3 B
4 B
16 B
5 B ×1.6
7 A
3 C
6 B
7 B
8 A
9 B ×1.6
6 A
3 D
8 B
9 A
10 A
11
12
13 A
10 B
5 A
8 C
13 B
14
15

NOTES ON SPONDYLOMORUM QUATERNARIUM EHRENB.[1]

MALCOLM E. STICKNEY

All the members of the Volvox family command rather exceptional interest with botanists and zoöogists alike. Not only does their systematic position on the border line between animals and plants, and the fact that within the group various steps in the evolution of lower organisms including the evolution of sex may be traced, contribute to this interest, but their striking features of form and behavior and their sporadic occurrence has made them for the past two hundred years objects of much study. Spondylomorum, one of the simplest of the family, was first described by Ehrenberg[2] in 1848. Stein[3] later figured the adult colony with great clearness, and described certain phases of its life history and reproduction, presenting an account which stands practically without addition as representing our present knowledge of that form. Various observers have reported it as occurring in small ponds in certain parts of Germany, France, and upper Austria (De Toni[4]) in Europe, and in Connecticut (Conn)[5] in this country. Oltmanns[6] in presenting Stein's account of the vegetative habit and mode of reproduction of this form (the latter being given as essentially that of the vegetative reproduction of Gonium or Pandorina), deplores the insufficiency of our knowledge of this member of the Volvox group. It is with a view to making up this lack in certain few particulars that this very incomplete account is presented, based as it is upon studies extending over but a short time, and with a relatively small amount of material. It is expected that a more complete account may be forthcoming later, when more

[1] Contributions from the Botanical Laboratory of Denison University, no. x.

[2] Ehrenberg, C. G. *Monatsb. Berlin Akad.* p. 236. 1848.

[3] Stein, Fr. *Organismus der Infusionstiere*, 3:1. 1854.

[4] Detoni, J. B. *Sylloge Algarum*, 1: 534–559. 1889.

[5] Conn, H. A. A Preliminary Report on the Protozoa of the Fresh Waters of Connecticut. 1904.

[6] Oltmanns, F. *Morphologie und Biologie der Algen*, 1:134–163. 1904.

material may be at hand. The writer wishes to express his deep indebtedness to Prof. S. J. Holmes, of the Department of Zoölogy, University of Wisconsin, who very kindly furnished the material upon which this work was based, and whose suggestions in connection with the work were most helpful, and to his friend and pupil Miss Gertrude Lett, who made all the drawings here included.

For two years past Spondylomorum quaternarium Ehrenb. has been observed at Madison, Wisconsin, coming in in great numbers in aquaria containing old grass and dead leaves brought in from rain pools in early spring. The organism begins to make itself evident in such aquaria about ten days after the culture is started, rapidly increases in numbers for a few days, until portions of the aquaria are fairly green with masses of individuals, and then as gradually the culture dies out. All attempts to rear these organisms in the laboratory, other than in the above sporadic fashion, or to keep the cultures running for any length of time, have so far proved fruitless, although no more than tentative efforts to do this were made. The strong positive phototaxis which these organisms show makes their separation from the infusoria and bacteria of the culture water a very simple thing. By carefully transferring a pipette of material taken from the side of the aquarium illuminated by direct sunlight, to the shaded side of a small vessel of sterile water, and then almost immediately withdrawing a fresh pipetteful from the sunny side of the latter vessel, and repeating the process once or twice, a pure culture of Spondylomorum is readily obtained.

For the study of the grosser features of habit a method of preparation was employed which was suggested by Dr. Marquette of the University of Wisconsin in his work on the antherozoids of Marsilia. A drop of water containing a large number of individuals was placed on a clean slide and exposed to the fumes of osmic acid for a few minutes and then evaporated to dryness, thus fixing the organisms to the slide. The preparations were then stained with an aqueous solution of pyoktanin blue until the cilia were clearly brought out, when they were washed with water, again dried without heat, and mounted in benzole balsam. With rather dense organisms containing small vacuoles this method has proved very successful, as the contraction due to drying is slight, and certain details, including the cilia, are brought out with great clearness. Preparation of Spondylomorum made in this way show

very beautifully the mulberry-like habit of the colony, with its four alternating tiers of four cells each, as described by Stein; the cells loosely connected with one another by the interlocking of the long cilia (fig. 1). Other preparations were made from material fixed in the usual way with Flemming's weaker chrom-acetic-osmic mixture, embedded in paraffin, sectioned from three to six micra in thickness, and stained with Heidenhain's iron-alum hæmatoxylin or with Flemming's safranin-gentian violet-orange G. combination. Both staining methods yielded very good preparations, although those obtained by the triple combination gave, on the whole, clearer differentiation of the finer cell structures. No other methods of fixation or staining were tried. All the material for this study was fixed between the hours of sun-rise and eight o'clock on a bright morning, that of March 15, 1908.

With preparations of living material the colonies present a somewhat striking appearance as they move swiftly across the field of the microscope, rotating rapidly on their long axes. Evidently there is a strict coördination of movement among the different cilia of the various individuals of a colony, and a study of the behavior of these organisms would doubtless prove of great interest and value. In size the colonies are small, ranging according to their age from 15μ (very young) to 35μ (adult) in length, and from 12μ to 25μ in breadth. All the cells of a colony are alike in size, shape, and length of cilia. The individual cells are ovate in form, being somewhat more rounded in front and more pointed behind. The looseness of the union of the cells into the colony is shown by the numbers of individual cells which have become separated from the colony and are swimming about by themselves. The cells vary in size from 6.5 to 12μ long, and from 3.5 to 6.5μ wide. The cilia range from 22 to 35μ in length.

In each cell there is a single chromatophore of the Chlamydomonas type, deeply cup-shaped, the bottom of the cup being thick and filling the entire hinder end of the cell, while around the margin and extending forward it becomes very thin and shell-like. No pyrenoids are present. A red pigment spot is to be found on one side of the cell, usually not far from the nucleus. Two contractile vacuoles are present at the extreme anterior end of the cell, and these appear to contract alternately, as is the case with other members of the group. The nucleus is large and stands out very distinctly in well-stained preparations, surrounded by a region of

dense and strongly granular protoplasm. No nuclear reticulum could be made out in the resting nuclei, athough the nucleolus appears sharply defined as a deeply staining granule, apparently spherical and homogeneous in resting nuclei, and distinctly lobed in those which have recently divided (fig. 5).

The nucleus evidently divides with great rapidity in cells growing under favorable conditions, for while large numbers of dividing cells were found, and all stages in the reproduction of the colonies were freely represented, showing that nuclear division must have been taking place abundantly, only two nuclei in a state of actual division were found in the preparations studied. These division figures were both in late anaphase, with a clearly marked central spindle and chromosomes well drawn back toward the poles. The chromosomes appeared as very short rods, twice as long as wide, and while their number could not be made out with certainty, it was small, evidently in the neighborhood of six or eight. No centrosome could be distinguished, but the presence of the chromosomes in the polar regions would necessarily make it difficult to differentiate a separate centrosome body.

As has been noted, the cilia are four in number (fig. 2), and are nearly three times the length of the cell. They arise from a wart-like protuberance at the anterior end of the cell—the so-called "mouth-piece." In one preparation studied delicate fibers appeared extending back from the mouth-piece, between the vacuoles, to the vicinity of the nucleus. As these filaments were made out in but a single preparation it would be somewhat hazardous to attempt to identify them with similar structures of Dangeard[7] or Timberlake.[8]

According to Stein's account reproduction takes place in Spondylomorum essentially as in Pandorina and other members of the Volvox family, that is, by a division of the protoplast within the mother wall into sixteen daughter cells, which escape by the rupture of the enclosing membrane. The division, however, is not an internal one, but there is in every case a complete cleavage of the entire cell. Hence there is no "escape from the mother cell" on the part of the daughter colony, since the daughter colony was

[7] Dangeard, P. A. Etude sur la structure de la cellule et ses functions, Le Polytoma uvella. *Le Botaniste*, 8:1. 1901.

[8] Timberlake, H. G. Swarm-spores of Hydrodictyon. *Transactions of the Wisconsin Academy of Sciences*, 13: 486–515. 1901.

never enclosed in a parent wall. The first division in this cleavage process is as Stein suggested in the general plane of the long axis of the cell in most cases. The rule, however, is not absolute. The second division also usually approximates the plane of the long axis of the cell, and at right angles to the first. This division, however, is by no means as regular in its course as the first. The other two divisions apparently come in with no regularity whatever. It is of special interest to note that there is no rounding off on the part of the cell preparatory to reproduction. Cleavage takes place while the cilia are extended and the colony is motile. It is by no means unusual to see an old colony freely swimming about with each of its members in a four-celled, or even an eight-celled condition, and with no evidence of even the beginnings of a separation of the mother cells. Division appears to be simultaneous in the different individuals of a colony (fig. 7). As was indicated above, reproduction takes place in the early morning, and apparently goes on with great rapidity during periods of favorable conditions. It would be exceedingly interesting to follow the rate of growth and frequency of reproduction in these organisms, and determine the influence of external conditions, especially the periodicity of light and darkness and of heat and cold upon this phase of their activities. Nothing of this sort has been attempted in these studies. No evidence of sexuality has been observed.

Spondylomorum shows a number of features which would seem to place it in a position somewhat remote from the other colonial members of the Volvox group. The entire absence of a gelatinous covering for the colony, and the loose union of its individuals, and especially the mode of its reproduction by the entire cleavage of the cell, are all wholly uncharacteristic of the coenobic forms, and strongly recall some of the simpler unicellular members of the order. In fact it would not be hard to conceive of a Spondylomorum habit having its genesis in the entangling of the cilia of a unicellular form like Pyramimonas, a form evidently very near the orgin of the Volvocales, and the only member of the order resembling Spondylomorum in both lack of envelope and presence of total cleavage. Such a conception enables us to see in Spondylomorum an early step in the evolution of the coenobic habit in the Volvocales.

Granville, Ohio.
May 3, 1909.

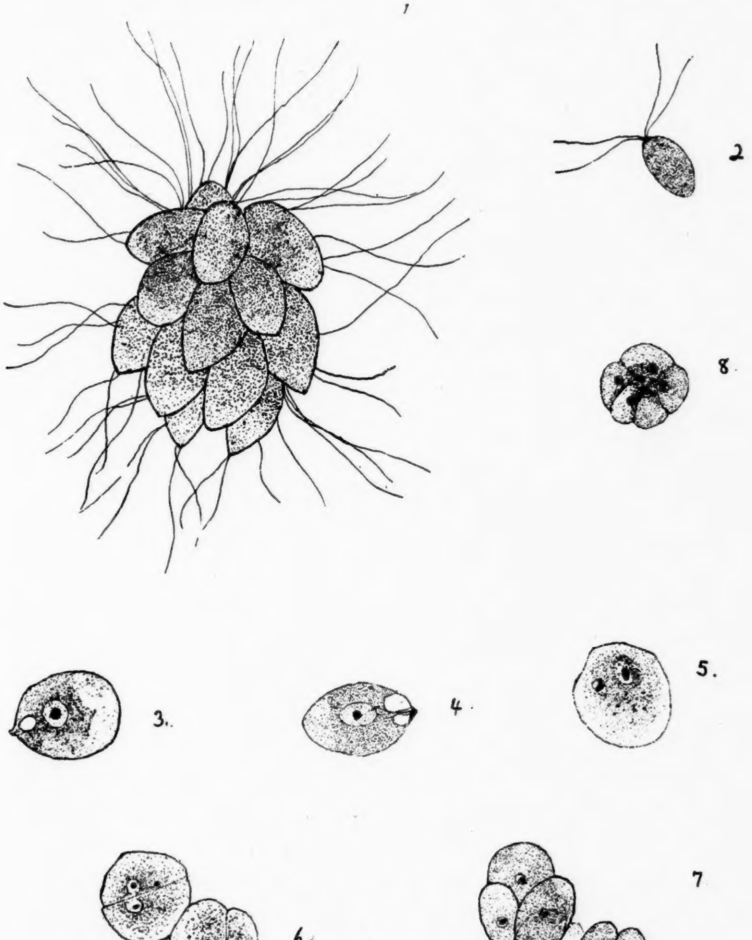
PLATE VI.

All figures were drawn with a camera lucida, using a Leitz $\frac{1}{12}$ oil immersion objective combined with ocular 4. The magnification here given is about 1500 diameters.

FIG. 1. Colony of Spondylomorum. General habit.
FIG. 2. Individual cell from colony.
FIG. 3 and Fig. 4. Longitudinal sections of adult individuals.
FIG. 5. Longitudinal section of cell immediately after nuclear division.
FIG. 6. Cell in transverse section, after first division.
FIG. 7. Group of cells after second division. Four-celled stage.
FIG. 8. Eight-celled stage, in nearly transverse section.

SPONDYLOMORUM QUATERNARIUM EHRENB. PLATE VI.

MALCOLM E. STICKNEY.



Gertrude Lett del.

THE REACTION TO TACTILE STIMULI AND THE DEVELOPMENT OF THE SWIMMING MOVEMENT IN EMBRYOS OF DIEMYCTYLUS TOROSUS, ESCHSCHOLTZ.[1]

G. E. Coghill.

Studies from the Neurological Laboratory of Denison University, No XXII.

In 1906 I began a series of experiments upon embryos of Rana and Amblystoma with a view to determining whether there is any regularity in the earliest neuro-muscular responses to tactile stimuli in the amphibian embryo. During the season of 1907 these experiments were continued upon embryos of Diemyctylus torosus, Eschscholtz (Triton torosus). Although the work of the first year gave interesting results and convinced me that the field of investigation was a fruitful one, it was less exhaustive and critical in its methods than the later work has been, and there is no occasion to give an account of it in this connection. It will, therefore, receive no further treatment here and all the data and discussions of this paper will relate exclusively to Diemyctylus torosus.

These experiments were originally planned for correlated anatomical and physiological studies. As an introduction to such work upon Amphibia they form the basis for the anatomical part, since they reveal distinct phases in the development of neuro-muscular response to the most primitive system of cutaneous receptors. But, apart from this significance to pure anatomy and physiology, they are, of themselves, an interesting contribution to the science of animal behavior, for they deal with a most important phase of behavior, namely, its very beginning in the embryo. If, for instance, there is any such thing as a "simple reflex," such as Sherrington suggests,[2] it must be found in the earliest reflexes of the embryo as observed in these experiments, and if it is possible to trace the

[1] Reprinted from *The Journal of Comparative Neurology and Psychology.* vol. xix, no. 1, April, 1909.

[2] Sherrington, Charles S. *The Integrative Action of the Nervous System*, p. 8.

development of a "simple reflex" into a form of acknowledged instinctive behavior, this link in the development of behavior would seem to appear in the development of the swimming movement as described in the following pages.

In view of this bearing of the experiments upon the subject of animal behavior certain results of the experimental part of my investigations are here made known before the anatomical phase of the work has been completed.

METHODS.

The embryos were removed from the egg membranes at various stages in development, ordinarily before they showed any sign of irritability to tactile stimuli. They were then placed in shallow Petri dishes, a single specimen in a dish, and tested from time to time for reactions. Usually an experiment continued until the animal began to swim.

The stimulus employed was a touch with the end of a rather fine human hair, mounted in such a way as to render the touch very gentle. The extreme sensitiveness of some very young embryos is remarkable. Even the touch of a fine piece of lint will at times evoke a vigorous response, as if it were a violent irritant.

Without critical consideration the tactile nature of this mode of stimulation might be held in doubt. The touch of a hair such as was used in these investigations might easily cause a considerable pressure, so that there might be a question whether the responses were to a strictly tactile stimulus or to a mechanical stimulus upon the muscles or central nervous system. Indeed, in the very early phase of development, when the irritability was for some reason unusually low, some of the reactions, I believe, may have been to direct pressure upon the muscles or central nervous system. But such instances, if they occurred at all, in these investigations, were, I believe, relatively rare. For instance, when the stimulus is applied to the under side of the head as the animal lies on its side, and the response is a movement of the head away from the side touched, it is inconceivable that this response is to a direct pressure upon the muscles effecting the movement, and it seems altogether improbable that such a stimulus could be brought to bear upon the central nervous system directly in such a manner as to give rise to a constant form of response. Or, in case the stimulus is applied

to the margin of the dorsal or ventral caudal fin and a movement of the head only results, as regularly occurs in certain phases of development, it is absolutely impossible for such a reaction to be given in response to pressure either upon the acting muscles or upon the central nervous system. As reactions of this sort occur here and there throughout nearly every one of my experiments, it seems to me certain that the stimulus employed was, with possible rare exceptions, purely tactile, and that, so far as the mode of stimulation is concerned, my conclusions are valid.

Ordinarily the stimulus was applied to the upper side of the specimen as it lay on its side on the bottom of the dish. Frequently however, it was applied to the under side of the specimen from beneath, in order to determine whether contact with the dish had any influence on the mode of reaction, but it was impossible to detect any factor of this kind in the responses. Some embryos, also, were suspended in an upright position and tested for the same purpose, and with the same result.

An individual record in detail was kept of each embryo from the time it was removed from the egg membranes till the end of the experiment. In the record of each trial, or application of the stimulus, the following factors were noted particularly: the region and side touched, the form of the response and the time of the trial. Tabulated schemes for rapid recording were tried in my first experiments of 1906, but it soon became apparent that such forms could not be adhered to, for they were necessarily based upon presumptions of some sort and were, therefore, a hindrance rather than a help to alert observation. These methods were wholly abandoned and have no part in the records from which this paper is written.

REACTION TO TACTILE STIMULI.

a. Response to Stimulation on the Head.

According to their reaction to a touch on the side of the head, in the region innervated by n. trigeminus or n. vagus, embryos of Diemyctylus torosus may be grouped according to three types, as follows:

Type I. Embryos which from the beginning and during a considerable period, respond regularly or almost regularly with a movement of the head directed away from the side touched.

Type II. Embryos which for a relatively short period at first respond irregularly with movements of the head toward or away from the side touched, and then enter upon a relatively long period of response like that of Type I.

Type III. Embryos which are at first asymmetrical in response, that is to say, they move their head in one direction only, regardless of the side touched, and then enter upon a short period of irregularity like the first period of Type II, and finally upon a relatively long period of response like that of Type I. Or individuals of this type may pass directly from the period of asymmetry to the regular form of Type I. The accompanying charts illustrate the behavior of typical specimens from each of these three types. The first column on the left in these charts records the serial number of the trials made, and the record of each trial is represented in the corresponding horizontal line to the right. The figures in the second column from the left record the time in hours and minutes that elapsed since the last preceding trial in each case. The diagrams in the third column from the left represent the form of reaction in the various trials. Where there is more than one diagram in a space these are to be read from left to right, and each represents a distinct phase in a series of movements. The arrow occasionally placed in these spaces indicates that a cephalo-caudal progression of the movement was distinctly observed. Where an "S" occurs the specimen swam, and the following diagram in the same space indicates the composition of the swimming movement. It should be noted that these diagrams of the movements are simply free-hand representations of the reaction according to written descriptions made at the time of trial. They cannot be considered as absolutely accurate in every detail, but they do represent truthfully the general order of the development of trunk movements in these animals.

The curves of the charts represent the side touched and the direction of the initial movement in the reaction relative to the side touched. The solid line records the direction of the movement of the head; divergence to the left from the vertical records a movement toward the side touched; divergence towards the right, away from the side touched; coincidence with the vertical, undetermined. The broken line records the side touched; divergence to the left signifies a touch on the left side of the head; divergence to the right, a touch on the right side; a blank, no record. Obviously,

where the two curves are parallel the movement recorded was to the left; where they diverge or converge the recorded movement was towards the right.

The apparent incompleteness in the serial numbers of the trials in the first column of some charts is due to the fact that in these experiments alternate or occasional trials were being made with reference to touch on the tail bud. The charts represent perfect series of trials with reference to touch on the side of the head.

The charts presented here are selected from a series which, with descriptions, has been deposited with the Wistar Institute of Anatomy and Biology, for the advantage of students who may be interested in a more exhaustive report of my experiments than this paper affords.

The accompanying table presents schematically some of the data upon which this classification into three types is based. It is the tabulation of the records of 36 specimens which have been selected solely upon the basis of completeness of the record and duration of the experiment. Owing to the difficulties in the manipulation of the work and unavoidable hindrances many experiments were not carried continuously through the entire period which is here under consideration, and, although contributing materially to the evidence on the problem as a whole, cannot, on that account, be included in a comparative study of this kind.

The several columns in this tabulation have significance as follows:

Column A. The number of the experiment, the data of which read to the right.

Column B. The time that elapsed between the last trial which gave no response and the first to which response occurred.

Column C. The time during which the embryo was asymmetrical in response.

Column D. The interval or time that elapsed between the last observed response that accorded with asymmetry and the first response that accorded with irregularity.

Column E. This is the second phase in the development of embryos of Type III, and the first phase of embryos of Type II. It is described above as the period of irregularity in response.

Column F. The interval or time that elapsed between the last observed reaction that accorded with irregularity and the first that accorded with the regular form of response as described above for Type I.

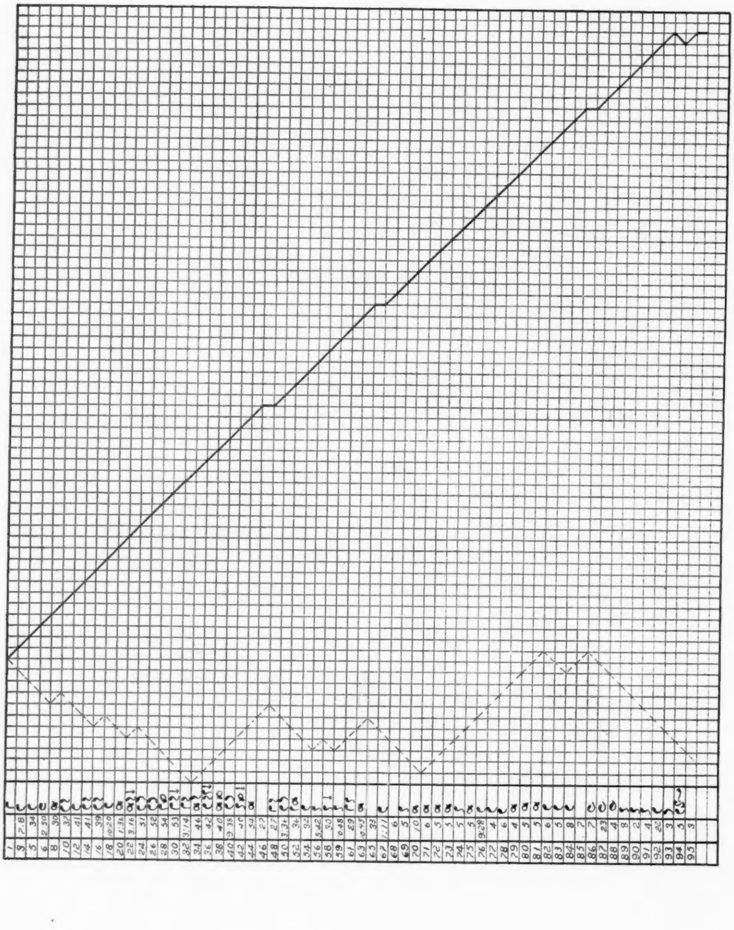


Fig. 1. Experiment 156, illustrating Type I. The embryo from which this record was made was the most regular of my series in response away from the side touched.

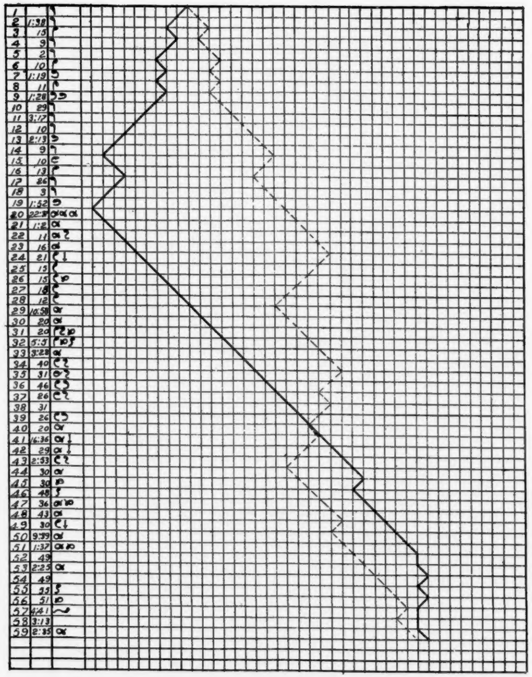


FIG 3. Experiment 136, illustrating Type III, in a case where the asymmetry passes over directly into regular response away from the side touched, but with a long interval.

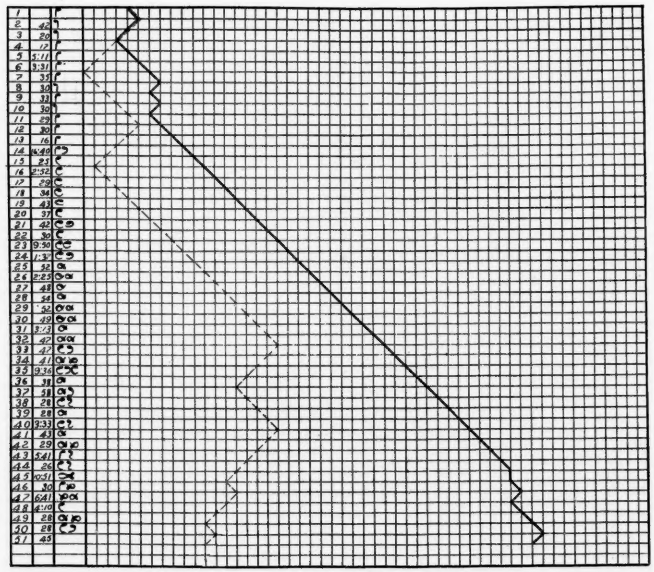


FIG 2. Experiment 151, illustrating Type II.

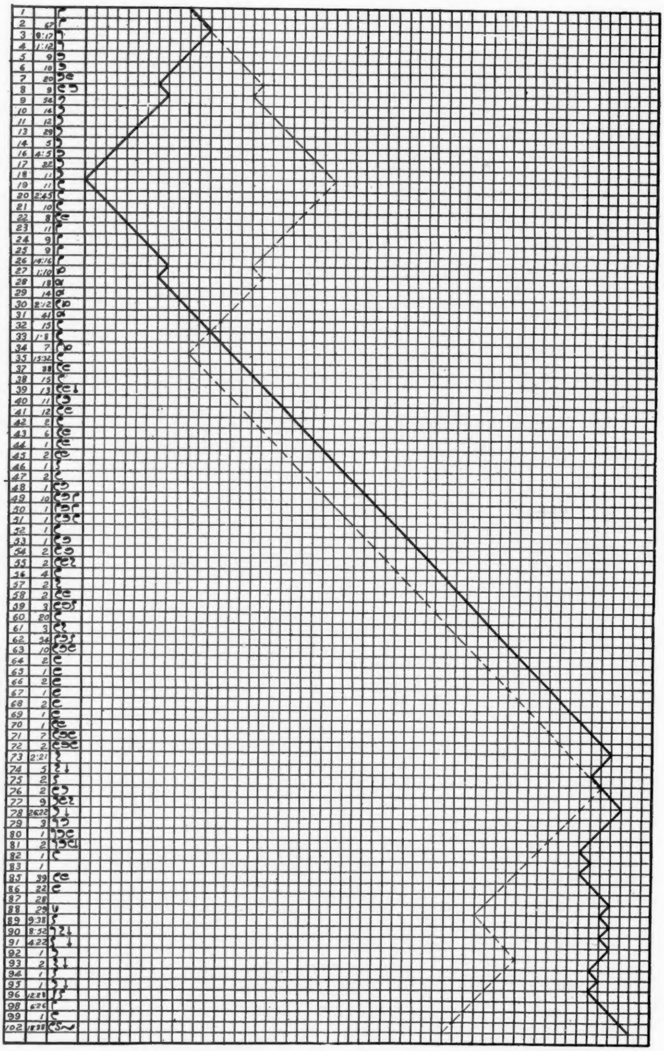


FIG. 4. Experiment 37, illustrating Type III, in a case where asymmetry in response passes abruptly into regularity, and the asymmetry is preceded by two movements at variance with it.

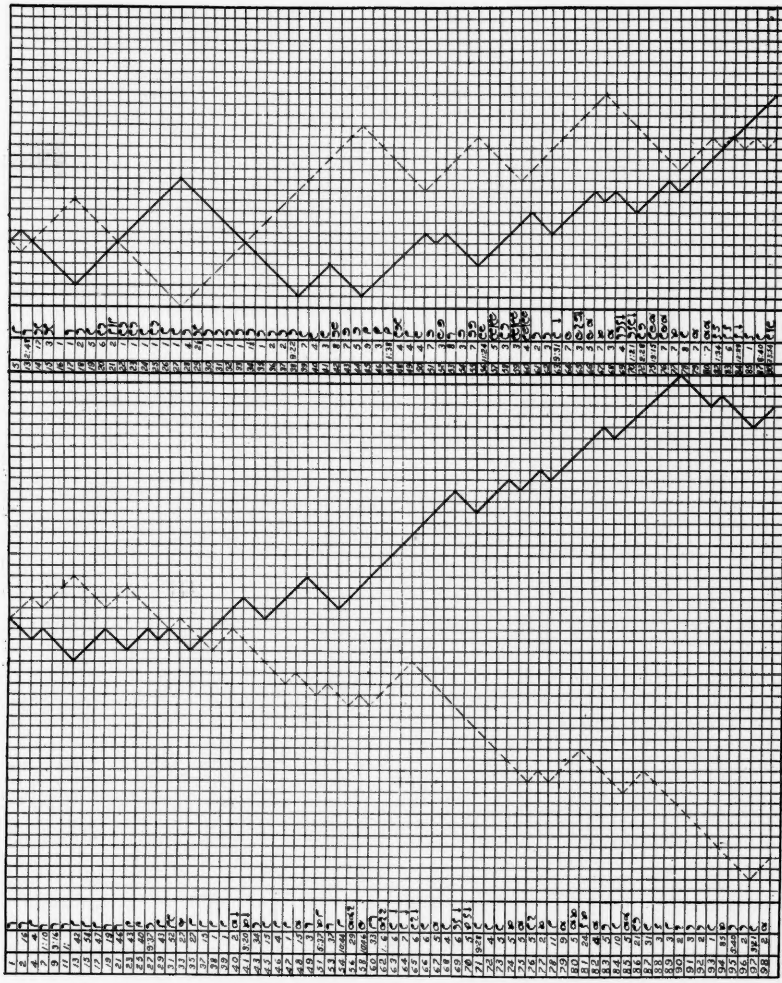


FIG. 5. (Upper figure.) Experiment 48, illustrating Type III, in a case where the period of irregularity is influenced, apparently, by the preceding asymmetry. It should be observed that the reactions were taken rapidly during the period of asymmetry and irregularity.

FIG. 6. (Lower figure.) Experiment 162. The embryo from which this record was made was, on the whole, the most irregular specimen of my series. Still, after the period af asymmetry there is a marked general tendency to move the head away from the side touched.

For further data see Table, p. 92.

A	B	C	D	E	F	G	H	I	
45	?	....	....	....	....	64:36	31	96.7	Type I.
32	?	....	....	....	....	52:07	53	94.3*	
146	24:00	....	....	....	....	72:00	40	100.0	
150	24:00	....	....	....	....	96:14	49	95.9	
145	24:00	....	....	....	....	73:34	40	95.	
144	20:22	....	....	....	....	67:52	35	97.1†	
156	13:30	....	....	....	....	96:43	57	100.	
Average..	21:10	....	....	....	....	74:43	305	97.4	
151	:20	....	....	12:19	:19	70:49	34	100.	Type II.
143	20:00	....	....	6:42	:19	48:09	25	96.	
147	5:45	....	....	2:27	11:00	71:09	35	91.4‡	
148	5:18	....	....	2:04	:14	64:41	24	100.	
149	?	....	....	1:35	:17	81:37	37	97.2‖	
374	3:53	....	....	1:52	9:29	49:02	37	100.	
142	20:00	....	....	6:29	:12	47:58	27	100.	
155	1:30	....	....	4:36	:27	59:04	23	100.	
158	24:00	....	....	11:49	:39	47:51	23	95.6‖	
161	?	....	....	:26	1:23	59:15	25	92.	
163	:41	....	....	5:10	:42	64:57	38	94.7**	
154	1:30	....	....	6:18	17:24	47:17	27	92.5	
140	1:30	....	....	8:34	:10	93:31	41	87.8	
141	14:00	....	....	33:21	:11	32:39	31	93.5	
36	?	....	....	26:47	14:01	37:34	19	94.7	
Average..	8:12	....	....	8:41	3:47	58:22	446	95.	
136	?	14:51	....	....	22:27	64:51	33	96.9††	Type III.
152	5:20	7:12	....	....	:58	58:04	22	100.	
159	2:54	8:26	....	....	10:22	69:13	24	91.6	
153	5:25	5:26	....	....	:43	66:10	32	96.8	
37	24:00	32:26	....	....	15:32	32:36	53	98.1	
39	?	:38	....	....	15:52	50:22	26	100.	
157	:14	7:31	....	....	2:39	72:53	30	96.6	
162	12:00	12:35	9:37	2:32	:27	45:08	46	78.2	
164	:40	23:48	5:38	11:59	:29	34:49	20	95.‡‡	
139	1:28	10:04	:22	2:26	22:45	68:12	39	97.4	
137	9:00	16:38	:07	6:26	22:44	62:25	33	93.3	
126	20:00	5:38	18:48	4:01	:09	98:48	60	98.3	
160	12:00	12:18	:43	:41	:41	58:36	37	89.1	
38	24:00	4:13	3:44	4:26	14:16	115:58	30	80.§§	
Average..	9:45	11:33	5:34	4:30	9:17	64:08	489	93.	

* The first 30 responses, distributed through 23 hours and 13 minutes, were all directed away from the side touched.

† During one period of 41 hours and 31 minutes there were 30 consecutive responses away from the side touched.

‡ During one period of 46 hours and 13 minutes there were 22 consecutive responses directed away from the side touched.

‖ During one period of 57 hours and 36 minutes there were 25 successive responses directed away from the side touched.

§ During one period of 36 hours and 50 minutes there were 18 successive reactions directed away from the side touched.

** During one period of 41 hours and 32 minutes there were 19 successive responses directed away from the side touched.

†† During one period of 47 hours and 6 minutes there were 25 successive reactions directed away from the side touched.

‡‡ During one period of 22 hours and 59 minutes there were 17 successive movements directed away from the side touched.

§§ There were in all 52 responses, distributed through a period of 137 hours and 33 minutes. Of these responses, 40 were directed away from the side touched, a percentage of 76.9.

Column G. The time during which the embryo is considered as moving its head regularly away from the side touched.

Column H. The number of responses given during the period represented by Column G.

Column I. The percentage of the responses indicated in Column H that were away from the side touched.

The time is recorded in each instance in hours and minutes, excepting in a few instances in Column B where the time was not determined. Averages are given in the several columns for each of the three types, excepting in Column H where the corresponding numbers represent totals.

With reference to the side touched in each trial my records are complete, but, inasmuch as the records in Column G clearly have no references to the side touched as determining factor, this element of the question is omitted from the table.

A comparison of the averages in Column B of the table might be interpreted to mean that the specimens of the second and third type came under observation relatively earlier in the period of development than did the specimens of the first type. But it should be noted that the figures in Column B represent the maximum possible time of irritability before the observation of it began. On the other hand, a comparison of the averages in Column G shows a clear distinction between Type I, on the one hand, and Types II and III, on the other. There is a difference of, say, 10 to 15 hours in the length of the period of regularity in moving the head away from the side touched. Furthermore, if the average of Column G for Type I be compared with the corresponding average for Type II plus the averages of Column E and F of this type, it will be seen that the embryos of Type I were longer in passing through the one period of regularity than were the embryos of Type II in passing through the periods of both regularity and irregularity, including the interval. It would seem, therefore, that a period of irregularity has not been passed over unobserved in Type I, and that the distinction between these two types is not based on the relative age of the individuals when they came under observations.

A similar comparison of the corresponding figures for Type III with those of Type I shows that the time represented by Columns E, F and G for Type III approximately equal that of Column G for Type I. But for the excessively long period of No. 38 in Column G, the comparison would result about the same as that

with Type II. But when the period of asymmetry and the following interval is taken into account it is clear that the specimens of Type III were a much longer time in passing through the periods represented by Columns C, D, E, F and G than were the specimens of Type I in passing through the period of Column G alone. This would seem to indicate that the condition of asymmetry is due to a precocious development of one side of the neuro-muscular system rather than to a retarded development of the other side. At any rate the sum of the averages in Columns C and D for Type III is greater than the average in Column B for Type II. It would seem altogether improbable, therefore, that a period of asymmetry like that of Type III has been passed over unobserved in Type II.

While I do not place any great dependence upon this comparison of the averages in the table, I believe they do tend to show that the difference between the different types of reaction as observed in these and numerous other embryos is not based upon relative age but upon the relative development, and probably the variable physiological condition, of the various constituent elements of the neuro-muscular system. When a period of asymmetry occurs, it appears before the period of irregularity or regularity, and never follows either of the latter, excepting in rare cases when one or two movements right at the beginning of the experiment are at variance with the asymmetry (figs. 3, 4, 5, 6). The asymmetry clearly influences the irregular reaction in some cases so that the movements toward the side touched appear to be determined by a partial persistence asymmetry (fig. 5). But this is not always the case. The period of regularity persists, ordinarily, till near the time of swimming. The actual length of the period varies greatly in different specimens, but a comparative study of numerous specimens convince me that the regularity in response is purest for a period of about 48 hours.

The structural basis for a regular asymmetry in response must be in the ascendency of the effector system of one side over that of the other, rather than in structural difference in the receptor systems of the two sides. Two facts particularly support this interpretation: (1) All spontaneous movements (somatic) that have been observed in embryos which conform to a given asymmetry are in accordance with the asymmetry in each case, toward the right in dextrally asymmetrical specimens and towards the left in sinistrally asymmetrical specimens. (2) In any given asymmetrical embryo

the asymmetry is the same with reference to stimulation on the tail bud as it is with reference to stimulation on the head, and specimens that are asymmetrical in one respect are so also in the other.

The structural basis for a regular movement of the head away from the side touched must obviously lie in the ascendency of the descending tracts which decussate in the cephalic part of the central nervous system over the uncrossed long tracts which descend into the cord. In comparing this condition with the response to stimulation on the tail bud, it should be remembered that the path from n. trigeminus or n. vagus to the opposite musculature of the cephalic part of the trunk is through the descending axones of these nerves within the central system, while the path from the caudal nerves to the same musculature is through the ascending axones of the afferent nerves. This factor will be best considered in connection with the account of reaction to touch on the tail bud.

The most difficult phase of the problem to deal with by way of anatomical inference or in the framing of a working hypothesis from the point of view of anatomy is the occasional response directed towards the side touched and the period of irregularity in response that precedes the period of regular movement away from the side touched. It is possible that in such cases the impulse passes directly to the centers of synapse with the effectors of the opposite side and, in case these centers are inactive, returns by a commissural path to the corresponding effectors of the same side; or it might be that the connection with the effectors of the same side is through collaterals of axones which themselves pass directly to the opposite side, and that, in case the opposite effectors are inactive the impulse may flow over into the collaterals and effect a connection with the effectors of the same side. Two observations may be cited in favor of the latter hypothesis: (1) There is a perceptibly lower degree of irritability during the periods of irregularity and asymmetry in response. My experiments are not exhaustive on this point, but they afford a considerable evidence to this effect, and none to the contrary. (2) The irritability of an embryo may vary perceptibly within a comparatively short period of time. This factor has not been definitely correlated with irregularity in response, but it may be the explanation of the occasional movement towards the side touched during the long period of predominant regularity. Also the very rare irregular movement occurring before a period of asymmetry, as observed above, may have its

basis in this variable irritability, at some point in the neuro-muscular system.

In some such manner as indicated above my experiments permit of a provisional hypothesis to explain the occurrence of the early periods of asymmetry and irregularity in response of some embryos and the occasional movement towards the side touched, and warrant the conclusion that, for a period of about 48 hours, or more, following the first movements in response to a tactile stimulus, the reponse of a symmetrically developed, normal embryo of Diemyctylus torosus is regularly away from the side touched when the stimulation is applied to the fields of the n. trigeminus and n. vagus.

b. Response to Stimulation of the Tail Bud.

There is no marked regularity in the responses to touches on the tail bud. There is a slight general tendency in some specimens towards movement of the head toward the side touched, but no definite significance can yet be attributed to this tendency. It is clear, however, that specimens that are asymmetrical with reference to stimulation on the head are similarly asymmetrical with reference to stimulation of the tail bud, and that ordinarily the asymmetry with reference to the two points of stimulation extends over approximately the same period.

One other fact concerning the reaction to stimulation on the tail bud is established beyond question by my experiments. The first response to such a stimulus in the very young embryo is a head movement, and as the embryo advances in age this movement still begins in the head region and progresses caudad. Ontogenetically, then, the most primitive conduction paths of the medulla spinalis are longitudinal and afferent, and the crossed paths are secondary, excepting possibly in the most cephalic part where the medulla spinalis may be involved in the crossed paths between the n. trigeminus or n. vagus and the opposite musculature of the trunk. The two halves of the medulla spinalis, therefore, seem to be physiologically distinct during this phase of development. This fact of development reveals from a new source the fundamental nature of the longitudinal divisions of the cerebro-spinal system, at least of the somatic components, as they have been conceived by Herrick,[3]

[3] The Cranial and First Spinal Nerves of Menidia, *Archives of Neurology and Psychology*, vol. ii, and *The Journrl of Comparative Neurology*, vol. ix; also numerous later papers, mostly in this Journal.

Johnston[4] and others on purely morphological and physiological grounds. It also suggests that in their direct connection with the cephalic part of the nervous system the special cutaneous systems of fishes and amphibians accord essentially with the primary plan of the general cutaneous system.

It would be a difficult thing ordinarily to demonstrate that the receptive fields and afferent conductors become functional in an embryo before the effectors do, for through the effectors alone is the functioning of the receptor and conductor demonstrable. But if the skin of a given somite in the tail bud of an amphibian embryo of suitable age be touched there will be no perceptible response in the effectors of that segment, while response will occur in the older somites farther cephalad. Into this given caudal somite, then, impulses are pouring from the external world through the receptors and conductors before the effectors of that segment are capable of making any perceptible response whatever. If this is true of the more caudal somites, it may be assumed to be true of the head segments also, and the embryo may be regarded as existing under a storm of impulses of the receptive system for a considerable period before it has the ability to give expression through its effectors. How widely this order of development of the receptor and effector may be applicable, as a law, and what its significance may be are questions of interest. It is possible that the summation of subliminal stimuli in neuro-muscular reflexes rests upon this as a fundamental principle of functional development. It is possible, also, that Kappers[5] might correlate this precocity of the afferent system with his theory of neurobiotaxis, in which he assumes that the afferent conductors have influence over the effector centers to cause them to migrate, phylogenetically at least, in the direction of the maximal amount of stimulation.

[4] The Brain of Acipenser. *Zoöl. Jahrb.*, 1901; *The Nervous System of Vertebrates*, Philadelphia, 1906; and other papers in this Journal.

[5] Phylogenetische Verlagerungen der motorishen Oblongatakerne, ihre Ursache und Bedeutung. *Neurol. Centralbl.*, no. 18, 1907.

Weitere Mitteilungen bezüglich der phylogenetischen Verlagerung der motorischen Hirnnervenkerne. Der Bau des autonomen Systemes. *Folia Neuro-Biologica,* B., Nr. 2, January, 1908.

Weitere Mittheilungen über Neurobiotaxis. *Folia Neuro-Biologica,* B. 1, Nr. 4, 1908.

The Structure of the Autonomic Nervous System Compared with its Functional Activity. *Journal of Physiology*, vol. xxxvii, no. 2, 1908.

THE SWIMMING MOVEMENT.

The movements of Diemyctylus embryos are of two main types: (1) the flexure, which is a bending of the body in one direction only; (2) the "S" movement or reaction, which is a bending of the more cephalic and the more caudal parts of the body in opposite directions, giving the form of the letter S.

The flexure may occur in several varieties. It may be a "head flexure," which effects a movement of the head only; a "pectoral flexure," which affects slightly more of the trunk than the head flexure does; a "mid-trunk flexure," which is effected by the muscles of the middle portion of the trunk only; a "general flexure," which involves the bending of the whole trunk. In the mid-trunk or pectoral flexure the parts cephalad and caudad of the flexed part may assume positions parallel to each other, in the form of the letter U. This may be designated as the "U" reaction. The general flexure may be extended till the body assumes more or less a coiled condition. This movement may be termed the "coiled reaction."

The various forms of the flexure are not to be considered as essentially distinct, for, with possibly the exception of the U reaction, they develop gradually one into the other in the order mentioned. Nevertheless, the distinctions are useful for descriptive purposes.

The first member of this series to appear in the course of development of the embryo is the head flexure; the next is the pectoral flexure, and, as the embryo advances in age, the flexure extends farther caudad until it involves the entire trunk in a general flexure, and, finally, in a coiled reaction. In ontogeny, then, the flexure develops cephalo-caudad. This is true for responses to stimulation on the tail bud as well as for responses to stimulation on the head.

In the development of any particular flexure, pectoral, general or coiled, the same progression cephalo-caudad is observed. If the n. trigeminus or n. vagus is stimulated by a touch, the normal reaction is a head flexure, and, if the embryo is sufficiently advanced in age, this flexure progresses caudad until the whole trunk is involved. In like manner, if the touch is upon the tail bud, the response begins in the head region and progresses caudad. The physiological development of a flexure, then, is correlated with its ontogenetic development.

Now, so far as my observations go, the S reaction never appears until the embryo is capable of executing an extended general flexure, and rarely until it has actually executed a coiled reaction. Furthermore the S reaction is ordinarily first performed by a reversal of the head from an extended general flexure or a coiled reaction before the original flexure is completed in the caudal part of the trunk. This reversed movement of the head, in early stage of the embryo, may simply progress caudal till it reverses completely the original flexure; but when the movement attains its typical form it is a relatively short, quick movement, and, when performed in series, it becomes the normal swimming movement.

The occurrence of the S reaction in series has its origin, evidently, in a mode of response which appears very early in the course of development. It may be designated as the "secondary reaction." This secondary reaction is a movement that is made during the phase of relaxation from a direct response to an external stimulus. It is caused, probably, by a rhythmic process in the motor cells, or, possibly, by stimuli from the proprio-ceptive field. It may be of greater or less extent than the original flexure. It may, for instance, advance a general flexure into a coiled reaction. It is a conspicuous feature in the behavior up to the time when the S reaction appears.

Now, it is obvious that when the head is once reversed from a flexure into an S reaction, the secondary reaction would explain the second reversal, which is simply repetition of the initial movement. The successive reversals of the head may, then, be initiated as secondary reactions and the progression of the successive flexures caudad, in the form of S reactions, propels the animal forward.

Locomotion, therefore, in the amphibian embryo is dependent upon the progression of the flexure cephalo-caudad, and the cephalo-caudal progression of the individual movement is further correlated with a similar progression in the ontogenetic development of the reaction. Furthermore, it is clear that this order of development of function is correlated with the order of structural development of the central nervous system, as illustrated, for instance, in the order of closure of the neural tube. These correlations naturally suggest, further, that the necessity of locomotion may have been an important phylogenetic factor in determining the order of development of the parts of the nervous system in vertebrates.

Emphasis, properly, has been placed, by authorities generally,

upon the principle of cephalization as correlated with the organs of special sense; but these early movements of the embryo show, that so far as functional development is concerned, the most primitive centralization of the nervous system, ontogenetically, is in direct response to the demands of the motor system in its relation to locomotion, while the sensory system involved is not the special sensory but the most primitive, diffuse, exteroceptive field. It remains to locate exactly this primitive center of the cerebro-spinal system by correlated anatomical and experimental studies; but from the experiments alone, this center would seem to be in close relation to the cephalic musculature of the trunk. This is inferred particularly from the fact that a flexure in response to a touch on the tail bud begins in the head region and progresses caudad and is the same in form (without reference to the initial direction of the movement) as the flexure that follows stimulation of the head. All movements, then, regardless of the point of stimulation, must emanate from the same center. Into the center all impulses would seem to flow in order to be directed in such a way upon the musculature of the trunk as to give rise to locomotion. Clearly the development of an eye or ear as such in its earliest functional condition has no part in determining this region of centralization. The controlling factor in this centralization is the motor system: a cephalization in response to the prepotency of the requirements of effectors and not in response to the demands of the cephalic receptive fields.

Phylogenetically, then, the most primitive cephalization of the nervous system may have occurred, also, in response to the demands for locomotion and have given rise to a center of control in the region corresponding to the lower portion of the myelencephalon or the upper portion of the medulla spinalis. Quite in harmony with this suggestion is the convincing evidence that Johnston[6] presents for the migration caudad of the afferent roots of the cranial nerves. Such a change in their course would lead them more directly into this primitive locomotor center. Upon this hypothesis, also, the economy of the arrangement of the special cutaneous nerves of fishes and amphibians is obvious. It is not to be supposed that the cephalization of the locomotor effectors is, in any respect, a direct cause of the cephalo-caudal migration of the

[6] *The Nervous System of Vertebrates*, chapter iii.

special cutaneous receptors and conductors, but such a cephalization would certainly favor the development of such systems, for, as already suggested, their peripheral conductors hold essentially the same relation to the cephalic part of the central system as do the most primitive central conductors from the trunk.

It should be noted here that a certain amount of locomotion may be acquired by an amphibian embryo by other movements than the S reaction as described above. The body may be flexed, for instance, and straightened by a series of secondary, vibratory movements. Such a reaction propels the animal on its side in a circle or spiral path. Also, a rapid succession of reversed flexures, in which no S reaction can be detected, may give swimming in a zigzag, erratic course. But normal, upright swimming in a direct course is, according to my observations, attained only through the perfecting of the S reaction and its performance in series.

As already suggested, this development of the swimming movement is of interest from the point of view of animal behavior. We now see that swimming, which may be regarded as instinctive in these forms, arises as the elaboration of the simplest known reflex in the embryo, the contraction of the most cephalic trunk muscles. Certain forms of the flexure, such as the U reaction and the coiled reaction, do not seem to be in the direct line of the development of the swimming movement, being simply intensive or tetanic forms of the ordinary flexures. On the other hand, the other types of flexure develop in a regular order and in a remarkably constant manner into the movements of locomotion. Now none of these simple flexures can be regarded as having any value as trials, since the Diemyctylus swims perfectly upon leaving the egg membranes in the normal course of development, and within them it can gain no practical experience for swimming out of movements of any sort. Instinctive swimming, therefore, and the simplest reflex alike, are inherent in the neuro-muscular system of the embryo, and while the former develops in a regular order out of the latter the movements themselves, which conform to this order, can have no selective value. The question naturally follows whether in forms which do not admit of such early experiments, such as birds, many quadrupeds and primates, the various forms of locomotion, as well as other forms of behavior, which, in a greater or less degree, appear to develop out of a series of trials, may not conform to the same law. It seems altogether possible that in such cases, also,

the so-called erratic movements may have only a trophic value. As such they would be essential to the perfecting of movements, but would have no directive value in the development of responses.

If, moreover, this hypothesis is valid for the ontogenetic origin and development of instinctive behavior it would seem plausible, also, as a theory of phylogenetic development. Its application to phylogenesis, though, would clearly be in opposition to the idea, which is accepted by various psychologists, that instinctive behavior has somehow been reflected back into the race from the intelligent type,—or, psychologically expressed, that instinct is a phylogenetic derivative of intelligence. For the latter hypothesis, I am not aware that there is any direct, experimental proof, while we do see, in such vertebrates as Amphibia which admit of early experimentation, instinctive behavior (locomotion) developing directly out of the simplest known reflex. However, while we seem to have a definite conception of the psychic parallel of the former (instinct), the concept of the psychic parallel of the latter is much less definite, and largely disregarded by psychologists. Yet it would seem that in the ontogenetic developments of the psychic life of Diemyctylus there must be quite as definite a reflex psychosis concomitant with the earliest and simplest reflex as there is an instinct psychosis with the later instinctive behavior in the form, for example, of locomotion; for, although the neuroses of the simple reflex are evidently not as elaborate as are those of locomotion, they are quite as definite in form. But, however this hypothesis of the relation of the instinct to the reflex may appeal to the psychologist, an adequate knowledge of the behavior of Diemyctylus must take into account the origin and development of locomotion from the simple reflex; for this reflex represents the simplest known physiological unit of the somatic neuro-muscular system, or of the somatic "action system." The relation of this unit to any of the more complex neuro-muscular processes is certainly an essential factor in the problem of behavior, or of physiology in the broadest sense.

In presenting the mode of locomotion of the amphibian embryo it is not my intention to antagonize the current explanation of the propelling factors of the swimming movement of fishes, ordinarily described as being, in effect, the same as that of a sculling oar. The latter explanation, so far as I am aware, is offered with reference to the adult fish, and it might not apply to an embryonic or

very young fish. Quite conceivably, the swimming movement might become modified during growth, in response to changes in body form, modes of feeding and other factors of behavior; and it is still quite possible that in the adult fish there is a cephalo-caudal progression of movement which is obscured by other factors of special adaptation.

This contribution should not be submitted without reference to the splendid work of Paton[7] on the reaction of vertebrate embryos. This is the only paper accessible to me that bears in any respect immediately upon the work in hand. Paton's contribution, however, is chiefly upon the development of fishes, with merely a reference to Rana and Amblystoma, and is particularly devoted to the spontaneous movements. Such movements would seem to be much more common in embryos of fishes than in embryos of Diemyctylus. The latter, during the early phases of irritability to touch, may be under observation for hours without making a perceptible spontaneous movement of the trunk, cardiac and branchial movements not being taken into account in my work.

My approach to the problem of physiologico-anatomical correlations in the development of the neuro-muscular system of vertebrates differs materially from that of Paton's method. Paton undertakes "to determine in a general, but not in a specific way" how far the reactions are dependent upon "the functional activity of a nervous system" and dismisses the study of specific reactions as impracticable, on account of the "apparently conflicting" data; but my work clearly demonstrates that, in response to the stimulus employed in my experiments, embryos of Diemyctylus have a very definite and regular mode of response, during certain phases of development. In fact I have yet to find the first individual that, through any considerable period, reacts contrary to the mode described in this paper, that is to say, no embryo has yet come under my observation that regularly moves its head toward the side touched when the stimulation is on the head. Nor have I found a single embryo that, observed for a considerable period, has not fallen under one of the three types which I have here described.

[7] The Reaction of the Vertebrate Embryo and the Associated Changes in the Nervous System. *Mittheilungen a. d. zoölogischen Station zu Neapel*, Bd. 18, Heft 2 u. 3, 1907.

THE RAISED BEACHES OF THE BEREA, CLEVELAND, AND EUCLID SHEETS, OHIO.[1]

FRANK CARNEY.

INTRODUCTION.

A Moravian missionary, Rev. John Heckewelder, came into the Tuscarawas valley, Bolivar county, in 1762. He traveled much throughout the State in his labors with the Indians, and in

[1] Presidential address read before the Ohio Academy of Science at the Granville meeting, November, 1908, representing work carried on under the direction of the Ohio Geological Survey. The author is responsible for the opinions expressed.

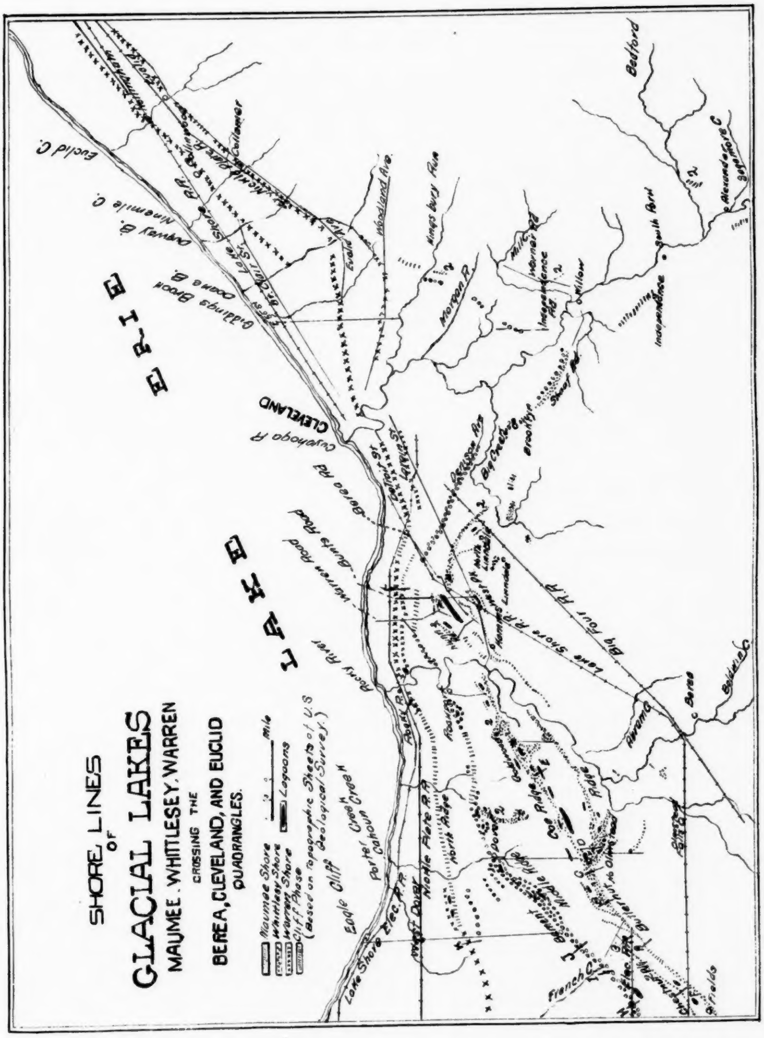

SHORE LINES OF
GLACIAL LAKES
MAUMEE. WHITTLESEY. WARREN
CROSSING THE
BEREA, CLEVELAND, AND EUCLID
QUADRANGLES.
LAKE
ERIE
CLEVELAND
Cuyahoga R.
Bedford
Berea

FIG. 1.

1796 drew a map of northeastern Ohio; on this map, he makes the first reference, so far as I can ascertain, to the Lake Erie shore lines. Accompanying the map is a brief description in which he refers more in detail to some of the deposits, now known to be of glacial and lake origin, about the lower part of Cuyahoga river.

In the second annual report of the Geological Survey of Ohio, published in 1838, on p. 55, Col. Charles Whittlesey refers to the beaches skirting Lake Erie. It would indeed be surprising not to find in these early documents references to the lake ridges—they are so conspicuous a feature of the landscape. The Indians selected these ridges for their paths, and the first settlers located their highways and dwellings on them. Colonel Whittlesey's comments are very brief.

The first even casual study of these beaches was by Sir Charles Lyell, the British geologist, in 1842; he followed two of the ridges for much of the distance between the Cuyahoga and Rocky rivers. He suggested methods by which they might be more correctly interpreted, lamenting that he did not have the time to ascertain whether fresh or marine shells were to be found with the gravels. He gave it as his tentative opinion that the "Middle Ridge"[2] (fig. 1) in particular appears to be subaqueous in origin.

In 1870, G. K. Gilbert studied the raised beaches in the Maumee valley; this work is probably the first rigorous study of shore-phenomena associated with ice-front lakes. Gilbert mapped the four beaches which indicated the levels of Lake Maumee and the succeeding bodies of water held up by the Erie lobe. Since his field of investigation was limited to the northwest counties of the State, he did not follow the beaches very far to the east nor to the north. Gilbert's methods of studying these ridges, as well as many of his conclusions, were entirely new to the science of geology; some of his interpretations he himself altered later.

The same volume which contains Gilbert's map on the beaches of the Maumee lobe, also contains J. S. Newberry's article on the Geology of Cuyahoga County; in this, Newberry devotes about four pages to the lake ridges.

In the succeeding volume of the Ohio Survey, A. A. Wright and J. S. Newberry published a more detailed description of these

[2] The discussion of these beaches can be followed to better advantage if you have at hand the three topographic sheets involved.

ridges between Elyria and Cleveland. Each ridge was traced for several miles at intervals; no attempt was made to give a detailed description of any particular beach.

From about 1890, the shore-phenomena of ice-front lakes has been given special attention by many trained geologists, either independent workers, State Survey men, or employees of the Canadian and United States Geological Surveys. The descriptions of, and references to, the beaches in the vicinity of Cleveland are numerous and have involved much labor in their correlation. The actuating purpose of each of these workers was the bearing that the ridges of a particular locality have on broader questions of the greater lakes' history; for this reason, we find very few close studies of any of the beaches.

The present investigation concerns the lake ridges of a narrow area; it attempts no contribution whatever to the larger problem of successive ice-front lakes. One of my purposes is the interpretation of the activities along present water-bodies from the standpoint of work done by water-bodies of the past. The activities of wave and shore currents of the present Lake Erie may be intelligently studied in the light of what these same agencies were doing when the lake was one hundred to two hundred feet deeper. At no place in the State can one find in such horizontal nearness, in more complete development, and in better preservation, the shore lines of former water-bodies.

GENERAL CONSIDERATION OF ICE-FRONT LAKES.

When the great ice-sheet attained its maximum development in North America, east of the Mississippi it extended beyond the divide of the present St. Lawrence drainage basin. This position was not reached by an uninterrupted progress. From the dispersion centers of Labrador and Keewatin the ice fed outward, sometimes maintaining a stationary front because melting and feeding were balanced, retreating when wastage was the more active, and advancing with the ascendancy of the feeding.

Wherever the great plain over which the ice was spreading sloped away from the ice, drainage moved freely; where, however, this plain sloped toward the coming ice, the water gathered, forming lakes.

The record of the bodies of water marginal to the Wisconsin

ice-sheet has long been known with much accuracy. As soon as the ice in its retreat came to a halt within the basins of the present Great Lakes, then frontal water accumulated; thus there were small lakes in the Michigan and in the Erie basins, while the remaining basins were buried beneath ice. These small lakes gradually expanded as the ice-cap diminished. So long as each lake maintained an independent overflow southward, it is evident that there had not been disclosed, in the area between these lakes, an altitude lower than the altitude of the overflow channels. As soon as any lower point was disclosed by the retreating ice then the marginal lakes coalesced and continued to drain southward by the lowest col reached. Frequently long intervals of time marked the spacing of these periods of retreat. It is this fact that makes it possible today to deliminate the extent of these temporary lakes. A time did come, however, when the whole front of the gradually receding ice-sheet was skirted by a body of water which reached the ocean by a single overflow channel. The first of these more expanded bodies of water overflowed by way of the Illinois river, past the present location of Chicago. A lower outlet was revealed when the ice withdrew from the Mohawk Valley area; then this great marginal lake reached the Atlantic by the eastern outlet.

The succession of ice-front lakes, as we today read descriptions of their succeeding overflow channels, include so many positions that we fail to comprehend the time involved. We feel that the shore line of any particular one of the present Great Lakes, as Superior, represents a long time period. We have difficulty, perhaps, in realizing that Lake Whittlesey, or Maumee, probably endured quite as long as the present Lake Ontario. When, however, we compare the rock cliffs now bordering the shore of Lake Erie, the constructed beaches, the barriers, the lagoons isolated by development of new bars, the dune sands reaching inland from the shores, with the identical phenomena of these lakes of the past and see how little they differ in scale, in spite of the denuding agencies that have operated upon them since they were formed, then we can better comprehend the very appreciable time intervals represented by the successive stages in the past history of the Great Lakes.

The shore of Lake Maumee in the vicinity of Cleveland was irregular because of the embayments occupying the Rocky river

and Cuyahoga river valleys. The arm of the lake extending southward into the former valley was crescent shaped, the western being the shorter of the two segments; but the prevailing winds, by constructing spits and bars, gradually brought that part of the shore into alignment with the general direction of the beach. A more detailed discussion of this is given later.

The valley of Big creek also formed a small bay during the early part of this lake stage; here again, on its western side, bars gradually developed and straightened the shore line.

The mature Cuyahoga valley was occupied by water of the Maumee level, reaching southward through the entire length of the Cleveland sheet. This arm was the drowned portion of the Cuyahoga valley, for the tributaries of which the lake constituted a local base level into which they spread deltas.

The shore of the Lake Whittlesey stage shows no evidence of a bay in the meridian of Rocky river; there was a slight curve in its outline where the water fronted the lower part of Big creek. In the Cuyahoga valley, however, this stage appears to have extended southward through the Cleveland sheet; its altitude is recorded by terraces cut into the deltas of the preceding stage, as well as by the extension of these deltas during the existence of Lake Whittlesey.

The Warren shoreline is characterized by but one embayment, that occupying the Cuyahoga valley which was ponded the entire length of the Cleveland sheet.

THE DEVELOPMENT OF SHORE LINES.

The processes involved in the development of shore lines are chemical and mechanical. The chemical factor is not of great consequence, though from one point of view it demands attention; the mechanical processes are really the ones that need consideration. Winds impel the water into waves and currents producing primarily two movements, on-shore and along-shore. The effectiveness of each movement is controlled directly by the velocity of the wind and the nature of the coast.

The work accomplished by these agencies is influenced in the first place by the nature of the material which the waves are attacking; if the coast is rock it yields less readily than do unconsolidated deposits; in the second place, by the profile of the beach

and off-shore slope. Ultimately these agencies under normal exposure to waves will bring about a fairly uniform and constant profile which is a gentle long slope into deeper water. The time required for a given body of water in a particular locality to produce shore line structures, depends very largely upon the original outline of the coast: if sufficiently irregular, and if it yields quickly to these denuding agencies, a supply of material will be at hand for constant work.

It is in the production of this material that the chemical process figures. In the presence of water, chemical disintegration is facilitated. This is important even when the coast being attacked consists of unconsolidated deposits. The basic elements of glacial drift break down more readily, leaving the acidic for distribution by waves.

But the more effective work in the preparation of material is accomplished locally by the waves of translation which erode the shores producing bluffs, that in turn are under-cut by wave-impact and the tools the water has in it. This on-shore movement of water likewise grinds the constituents of the beach, rounding and diminishing the size of all the stones. The along-shore movements also do much attrition work. Furthermore, as the waves of greater size break off-shore, they pick up bits of rock, dashing them again to the bottom, thus continuing the work of attrition begun nearer shore.

All this material is being distributed likewise by the water. Beach ridges represent the ascendency of the work of water moving on-shore over that accomplished by the water moving outward, that is, the undertow. Whenever the dash of oncoming waves drives material up the slope beyond the effective reach of the undertow, that material becomes part of the beach ridge. The ridges represent the work of unusually strong and more directly on-shore movements; an equally powerful on-shore wave, striking the coast obliquely, is not so effective in constructing ridges. Since the beach ridge, then, represents a differential of these quite opposing movements of water, it follows that the shape of this ridge is also the result of this difference. The undertow cannot carry any save the smaller bits of rock, and only the finer portions are carried very far off-shore. Material in suspension is always the finest product of destructive work and will be taken farthest from the shore line. The front slope of a beach ridge has a long gentle

gradient, save at the edge of the water, where, for a short horizontal distance, the angle is sharper; the back-slope often has a short, sharp angle, and stands more conspicuously above the coast (figs. 2, 3).

When the waves do not strike the shore directly, the oblique movement sets up an along-shore drift; this along-shore drift is a more active distributing agent when the coast is parallel to, or but slightly transverse to, the direction of the prevailing winds. The outlines of these high-level lakes were in general concentric with the present Lake Erie, the shore of which is well exposed to the sweep of the prevailing west winds. It is due to this relationship that headlands have been removed and their products distributed to the east.

Where an angle of water extends into the land, we generally find a *spit* gradually growing out across this reënterent from its windward side. The along-shore movement of water distributes material in a straight line unless some stronger force tends to deflect the line of deposition. Such a deflecting force is present when we find translatory waves passing landward through the deepening area of the bay; then the spit is bent inward in the shape of a hook. As the height of the spit increases from its tied end, the effectiveness of this deflecting movement is tempered, and we see in consequence, that the spit continues its development in a straight line, leaving the hooked portion as an irregularity on the back slope of the spit; when the bay has been completely shut off, this constructed form is called a *bar*. It not infrequently happens that spits are developed outward from either side of a bay, sometimes uniting, and sometimes passing each other, thus isolating the bay.

In the construction of spits from the windward angle of the bay, sometimes intervening areas are isolated and form lagoons. These lagoons may be developed in series, as when the spit terminates in a hook and later continues to grow forward; more often, however, the lagoons have long axes parallel with the trend of the bars.

Through the interference of shore currents, such interferences often arising from deflected movements of water, the loose materials instead of being carried continuously parallel with the shore, are so deposited as to form a cape which gradually grows out into the water. This constructional form is termed a *cusp*.

When the shore slopes gradually into deeper water, the higher

waves break some distance from the shore; the work then done is similar to that accomplished by strong waves breaking at the water-margin, that is, material is piled up; this piling up of detritus in deeper water develops a *barrier* which is, in reality, a submerged beach ridge; barriers therefore, are parallel to the shore. Much of the material which enters into the construction of barriers has been carried back from the shore by the undertow. In time the barrier grows higher, and accordingly interferes with the velocity of along-shore currents, causing the water to drop some of the load it may be carrying. From this time on, the barrier grows through these two methods; it may ultimately rise to the surface of the water and eventually form the shore line proper; when this happens, the space between the beach ridge or cliff, and the barrier, becomes a lagoon.

We sometimes find a cusp fringed by a barrier; the process of its development is identical with the method above discussed. Between this barrier and the cusp, a lagoon may appear. The barrier may or may not border the entire cusp.

Islands, and shallow places due to irregularities of the lake bed, interfere with the movements of the water; the former undergo wave and current erosion, thus supplying materials for the construction of spits, etc.; the latter, when rising sufficiently near to the surface of the water, may check its velocity and thus grow upward through the accession of deposits. With the continuation of this process, an island may appear, and from it spits will develop with the course of the prevailing winds.

LAKE MAUMEE LEVEL.

I will describe these beaches from west to east across the Cleveland area (fig. 1). The altitude usually assigned to the Maumee level ranges from 765 to 785 feet. This lake was about 200 feet deeper than Lake Erie. Two stages are indicated by a higher and lower beach varying 15 to 20 feet in altitude.

From Fields east to the Elyria traction line this shore consists of a cliff and terrace cut in the glacial drift (fig. 2, A); the terrace bears some gravel; thence to the vicinity of Kamms, which is just east of the Rocky river, it is made of gravel and sand. In places this beach has a steep back-slope; throughout most of the distance, the front slope rises from 15 to 20 feet (fig. 2, B, C, D).

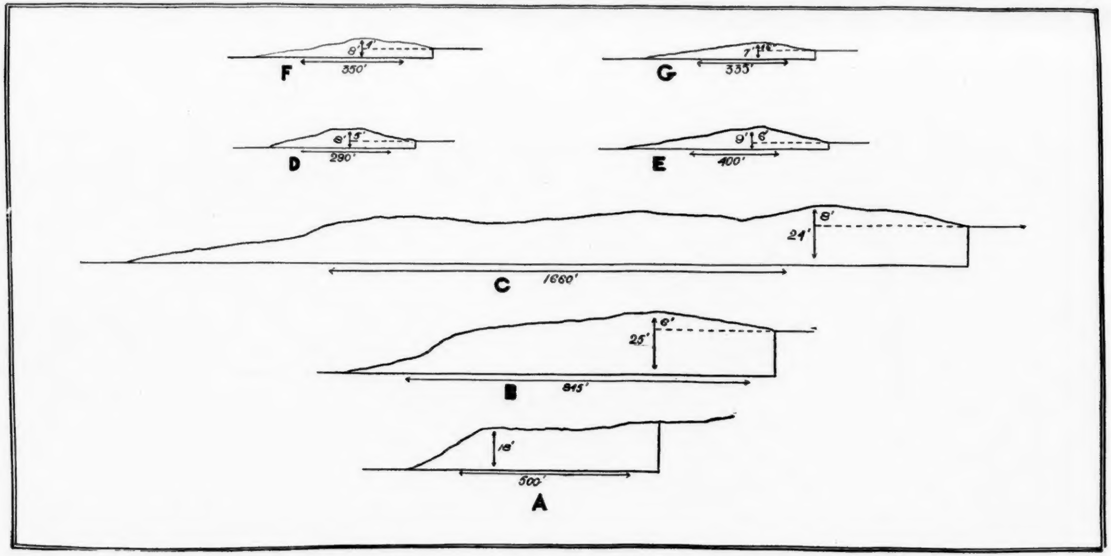


FIG. 2. Cross-sections A–D belong to the upper Maumee level; E–G, to the lower Maumee level. The location of the cross-sections may be found on fig. 1.

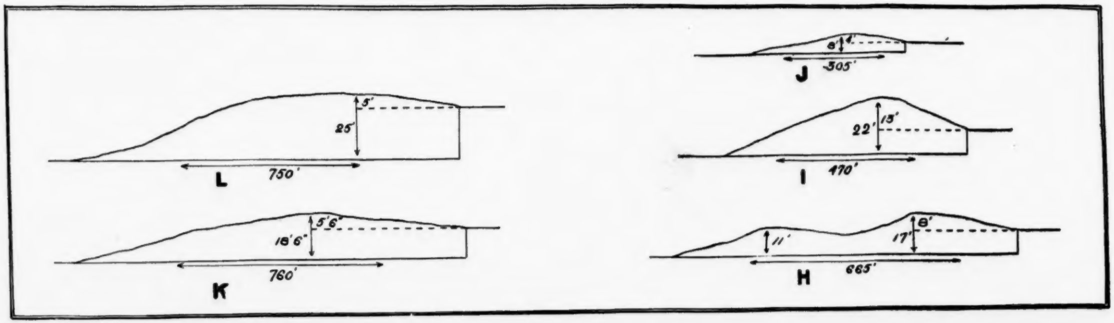


FIG. 3. Cross-sections H–J belong to the Whittlesey level; K and L, to the Warren level. For location of each cross-section consult fig. 1.

South-east from North Olmsted its constituents are fine to coarse sand, and less gravel. For a long period the region about North Olmsted must have formed a point or cape in the shore line as it marked the western limit on the Rocky river embayment. There is evidence of vigorous wave-action here; a few rods south of the corners at North Olmsted is a gravel ridge with a front-slope 3 feet and a back-slope 7 feet high, and containing stones as large as 3 inches in diameter.

The first barrier built in this embayment is traversed by a south-east-trending road connecting the two north-south highways south-east of North Olmsted; this barrier is about three-fourths of a mile long and consists chiefly of fine deposits. Its discontinuance westward where we would normally expect it to join the main ridge may be partly due to removal by erosion; eastward it flattens out and disappears within about one-fourth mile of the Rocky river channel. Inland from this I found no evidence of a beach, a condition due to the very low gradient and the consequent wide zone of shallow water. About one-half mile north of the west end of this barrier there is another ridge, terminating near the creek in a slightly recurved spit, apparently subaqueous in origin but later marking the shore line for a relatively brief period, after which it was gradually isolated by the development from the western shoulder of the embayment of still another spit.

The road extending south-east from North Olmsted traverses this bar which tended farther to shut out the Rocky river embayment; this bar is coarser in texture than the bar above described, and encloses in its rear several lagoons which were developed consecutively from west to east by the hooked growth of spits as the bar extended farther across the bay. This ridge continues to the edge of the present channel of Rocky river, and there is some evidence of it eastward from the river.

Returning to the shoulder in the main shore line at North Olmsted, we find at the present time a pronounced cliff, swinging at first slightly to the south and then continuing directly east. Between this and the bar last described, there are several marsh areas or lagoons, decreasing in number and size eastward, and each representing an inward bend or temporary hook-terminus of the spit. While this originated as a spit growing into the bay, it came in time to be a typical wave-constructed beach; its front slope is

gentle, rising in altitude from 10 to 14 feet; the back slope is nowhere very pronounced, owing to the leveling-up of the lagoon depressions. The beach averages about 10 rods in width; in places, however, the back slope is so slight as to make exact measurement impossible. Over the first mile of this beach, a highway extends, branching at the river into one road running directly north and another skirting the river channel; this latter road continues on a slight gravel ridge, the most pronounced phase of which lies to the east of the highway next to the river cliff. It is probable, however, that the complete development of the shore-ridge in this locality may not now appear for the reason that on its eastern side the river has undercut much of its width. After the first half mile, the beach lies entirely to the east of a highway, at which place it has been worked for a long time as a gravel pit; this is on the farm of W. F. Schultz. Proceeding, the highway again strikes the ridge which at no point for the next mile rises more than 5 feet above the general level; it discontinues within the next one-half mile, terminating directly south-east of Goldwood; but on the opposite side of the river about one-half mile south of Puritas Springs, we find this beach again, and can follow it without a break to within one-eighth of a mile of Kamms, where it becomes a cliff, cut in the Cleveland shale. A few rods east of Kamms, the cliff phase changes to a low gravel ridge which continues through and east of West Park.

In the vicinity of West Park the water deepened so gradually to the north, that no beach ridge was constructed; low spits, however, were developed, apparently of the barrier-type in origin, which were later somewhat modified as the on-shore waves succeeded in forming a true beach. One such spit turns sharply northward of the intersection of Lorain and Davisville streets. This relationship of ridges accounts for the slight lagoon just south-east of the corner at West Park. Other lagoon areas were developed within a mile north of this area, the principle one of which lies between the Berea and Warren roads; apparently, this latter lagoon represents a slight bay which was later enclosed by a barrier.

The West Park area presents some complexities in shore structure largely because of its proximity to the Big creek embayment. This embayment was in time completely shut off through the successive growth of bars.

The first of these spits ties to the main shore in the vicinity of Linndale, extending north-westward about one-quarter of a mile; this has a pronounced development, being from 5 to 15 feet in altitude; it consists of well worn gravel and sand. No spit correlating with this was found on the opposite side of the bay.

Extending southward from Lorain street, is another spit from 2 to 5 feet in altitude, and for about one-half mile continues a few rods west of Bosworth road, after which this road follows the ridge to Bellaire road, in North Linndale. The western tributary of Big creek runs parallel with this spit for about 80 rods.

Some scattered ridges of gravel exist south of Big creek on the opposite shore of this embayment.

After the Maumee lake level had finally established a continuous shore line across the valley of Big creek, the beach-forming agencies must have worked uninterruptedly for a long period. From the intersection of the Big Four track with the Berea road north-east of Rockport, eastward to the present channel of Big creek in the vicinity of the West Shore railroad, the shore is a beach-ridge and cliff averaging about 23 feet in height and having a sharp front slope. In the north-west part of Rockport village are depressions representing a lagoon developed in the growth of this beach, but eastward to the West Shore railroad, the ridge, simple in construction, consists of ordinary shore gravels. At the West Shore railroad, however, it divides; one of these divisions terminates on the edge of the creek bluff, but probably reappears again in a slight gravel ridge overlying moraine, south of the creek; the other arm, later in development, trends south-east, terminating in the bluff near West Park cemetery.

For the next one-half mile, I was unable to find any gravels, but the shore line appears to be indicated by a cliff cut in the moraine; nearing Brooklyn, however, beach gravels again appear. Street grading and other structural work have so modified topography here that one can not decide whether the ridge through a part of Brooklyn is of barrier origin, or of regular beach construction. South of Brooklyn, as the Schaaf road diverges to the east, the Maumee level is plainly marked; the highest part of the beach here bears much sand, suggesting subaqueous origin.

East from this point the higher Maumee level is not definitely marked. North of Independence, the slope has been steepened possibly by wave-work, and possibly by stream-work when the

glacier extended southward into the Cuyahoga valley, ponding the drainage which escaped westward along the edge of the ice. About a mile north of Willow along the Warren road, there is beach gravel, and north of Kingsbury run the rock slope appears to be wave-cut at an altitude correlating with this lake stage.

Returning to the western edge of the Berea sheet, we find a few rods north of this shore line what was probably a barrier, and later a beach, followed now by a highway, locally designated "Chestnut ridge". This ridge is about 15 feet below the shore line above described; it consists generally of fine sand; is from 4 to 6 rods wide and rises 8 feet on the average along its front-slope, which is very gradual (fig. 2, F, G). Between Chestnut ridge and the beach of the higher Maumee level, the interval is very mucky, indicating a former lagoon condition; to the east and north, this ridge blends gradually into the general level. Between this point and North Olmsted, two slender ridges, tied at their western ends to the beach of the higher level, trend with the old shore line.

From North Olmsted to the edge of the present river channel directly west of Kamms, is a sharply defined beach slope changing locally into a constructed shore ridge. Throughout this distance we have the permanent shore line for the lower Maumee level (indicated by 2 on fig. 1), marking the position of the water after the Rocky river embayment had been completely closed; the back slope of the ridge descends into extensive mucky areas which indicate the swampy condition that prevailed for a long period after the embayment had been shut off. Market-gardening is the chief industry in this section at the present time. The most conspicuous spit developed in the process of enclosing the Rocky river embayment is the broad-based ridge extending southward from Goldwood; opposite the end of this, extending northwestward from the other shore of the bay, is a correlating spit; apparently the two approached quite closely but have since been separated by erosion.

Proceeding eastward from Goldwood this shore line takes on more and more the form of a constructed beach, varying in width from 4 to 15 rods, and in height from 12 to 24 feet. Near the river it is slightly modified through erosion.

Another feature of this level of the Maumee stage is found in the off-shore bars which are not strictly of the barrier type. The second highway east of North Olmsted, running to the north,

passes along a north-south ridge of gravel and sand. Reaching eastward from the termini of this ridge are compound spits that represent the work of west winds. This bar and its appended spits with their like orientation indicate a shallow place in the water occasioned probably by a ridge of glacial drift. Smooth-surfaced till, rather stony in texture, is found in the fields east and west of this ridge. Wells sunk in the ridge also penetrate drift, but throughout its whole extent the ridge is covered with gravel from 5 to 14 feet in thickness. The spits that have grown from the ends of this ridge present several interesting features, especially in their constant trend to the east, in their gradual variation in texture from coarser gravels to fine sand eastward, and in the lagoons formed by the development of secondary spits from the windward side of the angle made by the main bar and the spit already developed.

A short one-half mile north-east of Goldwood is a cusp fringed by a barrier. The cusp is about 50 rods long; between it and the barrier is a lagoon.

Eastward towards the river, just before crossing the road which leads north to Rockport, is a short barrier with a lagoon in its rear. From the intersection of the Rockport road with the main shore, another ridge extends north-eastward; this, throughout nearly the whole of its one-half mile length, shows a strong development, in places 4 to 6 rods wide on top, and having a sharp back-slope.

Continuing eastward along this lower level of the Maumee Lake, we find on the opposite side of the river, west and north of the Rockport race track, a short slope due to wave work on the shales thus forming a cliff. For some distance this shore line is indistinct, but reappears about one-half mile northeast of Munn road, in a strongly developed gravel ridge which swings due east after crossing Warren road. It shortly blends into a low ridge of clay. The interpretation of this clay ridge was puzzling for some time; it is plainly not of glacial origin, and is so free from gravel or other normal wave-worn products that a shore line genesis did not suggest itself. In this vicinity, the Cleveland shale bears scarcely a veneer of glacial deposits. Wave action in consequence has attacked the shale, and because of the very low slope of the lake basin, cliff cutting did not take place. The shale was ground off by the waves and piled in a low ridge, so slowly

that weathering proceeded, it is thought, to a considerable extent before Maumee Lake fell to a lower level.

Going south from Warren road, along Brown road, one crosses two other slight gravel and sand ridges which alternate with lagoons. The southernmost of these formed the north shore line of the lagoon bay, already mentioned, which Brown road crosses before reaching Berea road.

Farther eastward, I have not noted any distinct shore-ridges correlating with this second Maumee level, except the possibility of such a ridge being indicated by the shore gravel extending south-eastward from the intersection of this beach with the West Shore railroad just north of Big creek. The front-slope of the beach along Schaaf road shows some evidence of being modified by the water of this lower level. The Tinkers creek delta has a cliff and terrace which apparently correlates with it. Northeast of Willow, on the slope east of a brick plant, are gravels at the proper altitude. And east of 87th street, between Union avenue, and Kinsman road, is another area of possible lower Maumee shore deposits.

LAKE WHITTLESEY LEVEL.

The altitude of this shore line is approximately 735 feet, or about 30 feet lower than the preceding stage. From the western border of the Berea quadrangle to the Cuyahoga river, it is practically unbroken, and for the major part of this distance consists of a gravel ridge, in a few places one-quarter of a mile wide, enclosing lagoons. The Cleveland, Elyria, and Western Electric railway enters the Berea sheet on this ridge, but after traversing it for a few rods, swings directly eastward to the shore ridge of the Maumee level.

Cross sections of the western part of this beach are shown in fig. 3, H–J. The compound characteristic of the ridge is apparent in section H. The low front-slope condition here indicated continues to characterize the ridge north-eastward as far as Bement; from Bement to Dover, the ridge is found in its most complex phase; through most of this distance, the outer slope is longer than shown in section J. The ridge top is much broader and for the second half of the distance we find a series of ridges alternating with longitudinal muck basins.

From Dover eastward to Rockport the ridge consists of gravel with a short front-slope rising 20 to 22 feet, and a back-slope dropping not more than 7 feet (fig. 4). The compound form of the ridge observed west of Dover is much less charactersitic of this portion; nearing Rockport, however, I have noted a few former swamp areas. The shape of the front-slope for several miles here indicates cliff-development, at the western portion in shale, and eastward, where the shore line crosses the buried Rocky river channel, in drift.

Crossing the Rocky river, the course of this beach is indicated for about one mile by Hilliard road, but at the intersection of West Madison avenue, the beach swings directly to the east, and changes from a gravel ridge to a cut cliff shown in the steep slope just north of this avenue. From Ridgewood avenue, eastward to the Lake Shore railway, the course of the beach is not definite; but upon crossing the Lake Shore, it comes in once more in its beach-ridge phase and thus continues to the neighborhood of the intersection of Fulton road and Denison avenue. From Lorain street almost to Fulton road, this ridge originated as a spit developing into the Cuyahoga embayment, and for over one-half of the distance, for some period of time, appears to have formed the shore while the other half apparently was still subaqueous.

From Fulton road to the western part of Brooklyn, whatever development this beach had obtained has since been obliterated by the erosion-work of Big creek. Its course through Brooklyn is somewhat doubtful because of street grading and other destructive work. The best exposure of the beach-ridge in this vicinity is along the west side of Broadview avenue just east of West 25th street; for about 80 rods the beach thus continues; it then swings southward across Broadview and flattens out. A short distance farther to the south I noted a wave-cut cliff parallel to Scarsdale avenue, which turns southward crossing Roanoke and Tate avenues. Beyond this point the shore of Lake Whittlesey was at first parallel to, and later coincided with, the lower beach of Lake Maumee. This horizontal coincidence has given the lower Maumee beach a steep front-slope, the difference in the level of the two lakes measuring the vertical distance through which the older beach may have been over-steepened. On the opposite side of the Cuyahoga river, about one and one-half miles north of Willow, we find parallel with Independence road, a bar one-half

mile in length; the southern part of this is nearly north-south in direction, but the northern half swings eastward in conformation with the outlines of the Cuyahoga embayment. Sand and gravel of contemporaneous development were noted along 59th street,

Fig. 4. Looking eastward along the Whittlesey beach one-half mile east of Dover

Fig. 5. Looking eastward across the Warren shore line at first highway south of West Dover; the cliff is here cut in shale.

south of Harvard avenue. For some distance northward this beach could not be definitely mapped since this interval has been worked over in the street development of Newburg, but for a short distance between 80th street and the Pennsylvania railroad,

there is a low ridge of gravel conforming in altitude with this lake level. For over a mile to the northward, I have not mapped any gravel or sand interpreted as representing Lake Whittlesey, but just south of the Fairmount reservoir, and parallel to Baldwin street, there is a low sandy ridge which indicates this shore.

From this point eastward I was unable to satisfy myself that the rock escarpment gives any evidence of wave work that definitely indicates the Whittlesey level; there are scattered salients which bear indefinite notches that may possibly indicate cliff-cutting of this shore; some of these benches may also be explained as the result of differential weathering. It seems preferable to state that the rock cliff which continues north-eastward from Garfield's monument for some eight miles is due to denuding agents in operation long prior to the ice invasion, and has since been altered slightly by the wave work of both the Maumee and Whittlesey levels.

LAKE WARREN LEVEL.

Lake Warren marks a vertical subsidence of the Whittlesey level; the drop is about 50 feet. The evidence west of Rocky River on the Berea sheet suggests that the subsidence was brought about in a very short time, but eastward from Rocky river there is an intermediate beach of slight development suggesting a gradual subsidence of the Whittlesey to the Warren level. This intermediate stage averages 20 feet above the Warren beach proper. From the Rocky river, to Ridgewood avenue, it is practically parallel to Detroit street, and consists of a low broad ridge of fine sand and gravel as far as Arthur avenue, while eastward the level is marked by a cliff cut in the Cleveland shale. The same ridge appears again along West Madison avenue, in the vicinity of 81st street; turning to the northeast, it crosses the Nickel Plate railroad, thence more directly east it crosses West 25th street, a short distance south of Lorain street. On the east side of the Cuyahoga the general direction of this beach is indicated by Woodland avenue, which follows the ridge for over two miles.

Just west of the Berea sheet in Lorain county, the Warren shore bears sharply to the north. This point of land extending into the lake acted as a wind break to the shore directly east. In consequence of this, the first two miles of the Warren shore on the Berea sheet consists almost entirely of sand and very fine gravel; the

beach contains a slight terrace (fig. 3, K), a cliff that averages about 20 feet, and for most of this distance, is a low ridge. A few rods east of the north-south road connecting West Dover and Bement, the Warren level is marked by a cliff cut in the shales (fig. 5), and this phase continues eastward for a little more than four miles. Contemporaneously with the development of the first mile of this cliff, off-shore deposits gradually widened the beach; throughout part of this distance, two or more barriers developed, giving rise to intervening depressed areas where marshes have persisted till the present time. A cliff and terrace characterizes this shore where it crosses the buried Rocky river.

Between the sandy beach on the west side of the sheet and the till terrace marking the site of old Rocky river, the interval of shales bears locally a few feet of glacial drift. Eastward of Cahoun creek, there is slight evidence of gravel accumulations at the base of the bluff.

Commencing three-fourths of a mile west of Rocky river, the top of the bluff bears a beach ridge, its crest rising three to four feet. Nearing the river, the ridge becomes composite, inclosing lagoons. Directly east of Rocky river, a cusp, developed from this beach, extends northward from Detroit street across the Nickel Plate railroad. For about two miles this beach consists of a sand ridge locally composite, and from 40 to 80 rods in width. Near Highland avenue, the beach gravels present a sharper front slope (fig. 3, L). Just east of this avenue, the shore line swings slightly southward, changing to a cliff cut in the Cleveland shales. In the vicinity of West 100 street, the Warren level is again indicated by a wide sandy beach, in places, reaching from Detroit avenue southward to Franklin avenue.

On the east side of the Cuyahoga, excepting about one mile west of Wade Park, the Warren level is marked by the Euclid avenue beach. From the vicinity of East 65th street, to the campus of the Women's College of Western Reserve University, the Warren shore is found north of Euclid avenue. Eastward as far as Collamer, a beach-ridge condition continues to the eastern edge of Euclid sheet. There is evidence that the Warren level did some wave-cutting in the shales, developing a gravel-bordered terrace that is wider in some places than in others, the control being a matter of stratigraphy. East of Euclid, the cliff-cutting work of this lake was more pronounced.

In the vicinity of the intersection of Ansel road and Superior avenue, I noted a conspicuous development of rather fine sand. Sand of the same level may exist westward, but on account of extensive building operations, tracing it was not at all satisfactory. Eastward from Doan creek, however, this broad, low ridge of sand may be followed without a break to the intersection of Penobscot and St. Clair avenues; from this point eastward, St. Clair avenue is located on this ridge of sand and gravel, and continues thereon to Nottingham. For three-fourths of a mile east of Nottingham, the gravel ridge is but slightly developed, but reappears again just before St. Clair avenue crosses the Lake Shore tracks; thence for one and one-fourth miles the gravel ridge swings a little north of the avenue and continues to the edge of the Euclid sheet. From Nottingham eastward, this ridge is not over three feet high, even where it is best developed, but west of Nottingham, the ridge in places is 5 feet to 10 feet high, and contains some rather coarse gravel.

This St. Clair avenue beach ridge is about 30 feet lower than the proper Warren level; its shape and continuity suggest a lake stage. West of the river nearly to Edgewater Park there is much sand and fine gravel at the same altitude. If, however, Lake Warren declined slowly, or by short stages, it is probable that the St. Clair ridge is only a barrier beach.

LIFE RELATIONS OF THESE SHORE LINES.

The flat region bordering Lake Erie has been likened to a coastal plain. There are several reasons for seeing a similarity. In the first place, the escarpment due largely to inequality of rock texture serves as a border for the low smooth strip that belts the lake. This flat bordering strip, as we have seen, is a terraced lake plain. Furthermore, the successive lake-stages have given the streams corresponding local base-levels, hence they have had a drainage history very unlike that of coastal plain streams. Organisms, flora and fauna, have been influenced by this particular physiography with its stretches of gravel ridges, rock cliffs, wide strips of sand and marshes, and extensive clay areas. And man, both Indian and white, dwelling here, has also experienced physiographic reactions. It is our purpose to look briefly into some of man's responses.

These old shore lines in their development witnessed the usual shifting facies of plant habitats, developing societies, and in time families and communities, working out the usual history that always takes place slowly under a changing environment. The ecology of modern shore lines under like climatic conditions must be very similar. Each stage of these high level lakes involved a great lapse of time. Some indications of this time are seen in the numerous swamp areas, many of which had not been eliminated by natural processes when the white man came into the area.

As soon as a given level of the lake gave way to a new and lower level, the deserted beach, as well as the area recently covered by deep water, were spread over by plants in their normal struggle. From the standpoint of the farmer, the plant history of this land is of importance. Residual rock alone does not make a fertile farm. He ploughs the soil which is reduced rock plus the remains of organisms; usually the more of this latter addition the better is his soil. A ridge inhospitable to plants is made artificially hospitable to crops only with the greatest of labor.

Beach societies were never prolific, for here flora always has a struggle and even after the withdrawal of the water insuring a static condition of the beach, the plant societies multiplied very slowly. For this reason humus accumulated slowly. Relatively, then, beaches were never fertile. The sand areas always associated with beaches, either through the development of spits, cusps, or deltas, have a more abundant flora, in consequence of which they have become richer for cultivation. The prolific plant life of lagoons develops an almost ideal soil. Many lagoons are found about the angles of embayments and between barriers and shores; these make rich lands.

Another relation of these shore lines, passive but of importance in the development of the region, is seen in their use by the Indian for trails and the white man for highways. In consequence of this influence, the farms front the shore-ridges, and the houses, in general, are placed on the front-slope where quick and effective drainage is best assured. The shape of the older farms, longer or shorter as the shores converge or diverge, again shows an influence of these successive lake levels.

Furthermore, there is observed in the agricultural evolution of this region a tardy adaptation to natural conditions. The first farmers here were emigrants from New England and carried on

general farming, extensive in its application. Land was cheap and there was plenty of it; population was sparse, hence markets were limited. Only the old staple lines of grains and fruits were cultivated. Even in a generation, the descendants of these New England emigrants learned that the muck lands associated with the ridges were especially adapted to the growth of onions; further than this, I have not been able to learn of much ingenuity on the part of these aboriginal farmers. Gradually as more distant outlets were found, the first through the construction of good stage roads, later through the digging of canals and the stimulated lake-navigation, and finally through the building of railroads, agriculture became more varied.

More thought was given to adapting crops to the soil. The broad flats below the Whittlesey level were found better suited to the growth of vineyards; the soil here is clay, for the most part either glacial or residual of the old shales. We note in this region at the present time further diversity, particularly where a low swell of gravel breaks the usual clay; these slight ridges may be located, usually by an apple orchard three or four rows of trees wide, but awkwardly long.

With the increasing city population, a growth made up very largely of foreigners attracted by opportunities of labor, there came increasing local demands; but the local farmer was tardy in responding to this demand; he was not so thrifty that he regarded his farm investment as a good one; in consequence, the provident foreigner from his days' labor relentlessly saved and so became a farmer. With this gradual supplanting of the New England farmer by the Danes, Germans, Bohemians, and Polanders, came the installation of European thoroughness in agriculture. Intensive and specialized farming rather than the former extensive method was inaugurated as these men became land owners. Farms that had been barely supplying the expenses of living for a Yankee family later formed the basis of permanent bank accounts. The beach ridges were enriched, crops adapted to them were grown; the sandy fields were so treated as to be made more dependable in times of drought; stubborn clay areas were drained and lightened. As the city of Cleveland continued to grow in population, market-gardening in the hands of these foreigners was made very profitable. These new emigrants from old Europe brought with them a training acquired through generations of ancestors

engaged in a struggle for momentary support. This training has made them more valuable as American farmers than as laborers in factories.

In still another direction, we find the lake ridges entering into life relations. For industrial purposes, such as building-blocks and concrete, they furnish a supply of gravel and sand; the extensive deposits of lake and glacial clays have afforded material for brick and tile.

We find a specially interesting physiographic reaction in the influence of the lake-made physiography on railroad construction. In this area, the Cuyahoga was the largest river tributary to these lakes. Into the lake at all stages, the Cuyahoga built an extensive delta and as the lakes dropped from one stage to another, tributary streams have incised this delta which is made up of sand, coarse and fine, and gravels of varying texture. It yields readily to stream work, consequently deep channels were developed. Its lack of stability near the walls of a stream is obvious; for this reason railroads have always hesitated about constructing high bridges.

All railroads centering at Cleveland have either east-west courses bordering the lake, or north-south courses paralleling the Cuyahoga valley. The Lake Shore, as the name implies, belongs to the former class. One other east-west road, however, the Nickel Plate, approaching the city from the east, turns southward near the south side of the delta and descends through the valley of Kingsbury run to the level of the present Cuyahoga river in ascending from which, on the western side, it uses another tributary valley. The Big Four uses this same valley west of the Cuyahoga.

The railroads from the south, that is, the Baltimore & Ohio, Pennsylvania, Wheeling and Lake Erie, with the exception of the Pennsylvania, enter the city through tributary valleys cut in the old delta. The Pennsylvania, however, follows Mill creek to Newburg, then it skirts the Maumee beach for two miles and gradually descends the delta slope to the lake front; the Baltimore & Ohio has a more uniform gradient as it follows the edge of the river channel.

But at the present time, a high level bridge is under construction; this is being built across the Cuyahoga on the delta-top level; it is a part of the recently located "Belt Line" which has become the property of the Lake Shore Railroad Company. From the standpoint of engineering, this is a hazardous venture, a fact which in

the light of the thousands of dollars spent by this company in the last year, much of which has been sunk in the slumping quick sands of this old delta, needs no further comment.

A vital question today in every large American city is speedy transportation for the urban part of its citizens. This fact has led to the construction, in many large centers of population, of subways. For the most part subways in the city of Cleveland would have to be cut through this old delta. Such an undertaking will doubtless present new questions to subway engineers.

This particular part of the southern shore of Lake Erie, if one can clearly interpret the present movement of industry, is destined to be the most thickly populated portion of Ohio. The lake plain here, so far as the city of Cleveland is concerned, even now is too narrow. It is probable that in this assured development many physiographic reactions, new to this region, will arise. This whole composite of conditions, then, is the result of a pre-glacial physiography upon which has been imposed the work of three lake levels, and which is becoming still further complicated by the shore line now in the making.

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